What's Known About Managing

EASTERN WHITE PINE

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Foreword

At the 1957 meeting of the Northeastern Forest Research Advisory Council the comment was made that although Eastern white pine has been the most studied forest tree species in the Northeast, the only literature on the management of the species was in reports on isolated and uncoordinated studies. There was no comprehensive compendium of knowledge.

From the discussion following this comment came a request that the staff of the Northeastern Forest Experiment Station assemble the known facts about white pine management, and that they present this summary at the 1958 meeting of the Council. This was done at the Council Meeting at Kennebunk Beach, Maine.

In preparing the presentation, the Station staff did not attempt a complete coverage of white pine as a timber species, such as a monograph would require. Neither did it attempt a manual on white pine management, such as a practicing forester or landowner might desire. Instead, a sincere effort was made to present to a select audience, and in the limited time available, a concise statement of the pertinent information available on the management of white pine under the conditions that exist today. The staff, with scientific integrity, reported not only what is known about managing white pine, but also what is not known.

The Council members considered the report sufficiently valuable to merit publication, and requested the Station to prepare the material for issuance as a Station Paper. This is it, in somewhat revised form.

Unlike most papers issued by the Station, this is not a report on original research by Station staff members, though such research results are included. The report contains little that is new, and little that has not previously been reported. Its contribution, if it makes one, is an orderly presentation, gathered from many sources, of the present state of knowledge related to white pine management.

A byproduct of this organization of known facts has been a much clearer perception of the gaps in our knowledge, and the seriousness of these gaps. Some are minor; some are great. Some may be bridged with the results of short-term studies. Some will require elaborate long-term experimentation. Some gaps may never be closed.

But knowing the deficiencies in our knowledge points the way to future research. Thus, by indirection, the Council has performed its true function in advising us of the need for further and intensified studies of this species.

Ralph W. Marquis

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'Eastern white pine is the king of American woods.'

This photo and those that follow were taken by Charles R. Lockard.

I

The Future for White Pine Management

Markets & Products for Eastern White Pine

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by Charles R. Lockard

EASTERN white pine is the wood upon which the lumber industry was founded in this country 300 years ago. For a long time this wood was the mainstay of the industry. In Europe, white pine was known as *the* American lumber species. From the earliest reports--from Spalding and Fernow (1899), through Frothingham (1914) and Betts (1941), to the Northeastern Lumber Manufacturers Association (1950)--those who know wood have come to the same belief: that eastern white pine is the king of woods.

Because of its unique combination of properties--its moderate strength, straight grain, soft and uniform texture, stability and ease of drying, and resistance to decay--the eastern white pine (*Pinus strobus* L.) is still regarded as the most intrinsically useful of all American softwoods.

The management of our white pine timber stands can be developed in the most rational manner if two questions are answered:

- Are there now, and will there continue to be, adequate markets for the amount of white pine that can be produced?

- What are the important use characteristics of white pine products that are subject to control by forest-management practices?

In this and the following papers we will give our answers to these questions.

MARKETS

Currently, about 5 billion board-feet of white pine and white pine-like species of lumber are produced annually in the United States (U. S. Forest Service 1958). About 70 percent of this is ponderosa pine, and 30 percent is the white and sugar pines. Of the total, eastern white pine comprises 20 percent or about a billion feet; three-quarters of it produced in the Northeast.

Since eastern white pine can be used effectively for most of the purposes for which ponderosa pine is used, the potential lumber market may be as much as 5 billion board-feet and not the 1 billion feet indicated by current production of eastern white pine.

PRODUCTS

All white pine moves from the forests as round products (logs and bolts) but only a limited amount is used by consumers in this form. More could be used in the round for fencing (posts and guard rails), for the wood has adequate strength and takes preservative treatment well. Less than 20 percent goes in the round to pulpmills, felt mills, and bolt mills. More could go to particle-board plants that do not now use round wood. Similarly, although the species is suitable for veneer, there are no veneer plants in the region that use it. The bulk of the round white pine products, then, goes to sawmills. This will probably be the future situation.

Thus, the need to control the character of sawlogs (as judged by lumber-quality requirements) is the primary factor influencing the culture of the species. Hence, the characteristics that control lumber quality must be understood. These characteristics are used as lumber-grading specifications. Lumber grades in turn are determined by the use requirements.

Uses for white pine lumber are too well known to require enumeration. A recent study of lumber consumed in manufacture in New York State showed 87 items in which eastern white pine is used. It can be used for any member of a house. It is also a standard industrial lumber species.

But white pine lumber now supplies only part of the potential market. In New York State as much ponderosa pine

as eastern white pine lumber is used. Why? The only apparent reasons are that, compared to white pine, ponderosa--

- Is aggressively merchandized and may be sold at lower price.
- Is exceptionally well manufactured and graded.
- Has high grades available in quantity.

The first 2 points, although not unrelated to the third, are matters for converters to cope with. But the last--lack of high grades--to a large degree stems from the condition of the white pine forest base and thus is of special concern to foresters and landowners. The fact that the annual harvest of eastern white pine sawlogs yields a poor grade-pattern of lumber is known. So the important questions are: What causes low-grade lumber? and how do we grow high grade?

Some of the factors that lower lumber grade are operational. Degraders such as blue stain, worm holes, and poor manufacture are the exclusive concern of converters, and can be controlled by them; foresters must be concerned with the rest. Some of these are of origin as yet unknown--bark pockets, pitch pockets, shake. Much research will be required to find a practical means of identifying and correcting the causes of these.

The cause and possible control of the major degrading factors are known. These factors are the twins--knot and rot. Knot effect is evaluated by size, tightness, and color. In general, high-value lumber carries at the most only a few very small tight knots. Increase in knot size and decrease in tightness lead to lower grade lumber. Allowable actual knot size is related to width of board; the narrower the board, the smaller the allowable knot.

Rot, the other major degrader, is not permitted in the highest grades.[1] In the premium grade, only 10 percent incipient rot is permitted on a board face. In the standard grade, 10 percent of soft rot is permitted, and in the industrial grade 50 percent.

Now the twins knot and rot can be controlled to a large degree by forest management; knots by pruning and proper log making, and rot by weevil control (Ostrander & Foster 1957). Width of board obviously is a reflection of tree size. Compression wood, another degrader, is a result of tree lean; so its occurrence can be reduced by management.

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[1]For list of grades and descriptions of them, see 'Standard Grading Rules for Northern White Pine and Norway Pine', published by the Northeastern Lumber Manufacturers Association, Inc., New York, 1956.

The twins are negative or degrading factors. It may be well to look at the reverse of the coin--at the major positive quality factor. This is *clearness*, or freedom from degrade. Completely clear boards are tops. But *partial* clearness is also near the top. A D-Select board, for example, is one with a clear face on a finish to standard back. Clear and sound board edges will permit certain unclear boards to remain in No. 1 and No. 2 finish. A third phase of clearness is clear internodes. Boards with 3- to 4-foot cuttings will make valuable No. 1 cuts. This, too, can be partially controlled in the woods.

The white pine weevil deserves very special notice, so far as lumber is concerned. It is a serious enemy because--

- It causes deformation that results in:
  Excessively degrading branch knots.
  Distorted and coarse grain.
  Compression wood.
- It causes crook that reduces yield of wane-free lumber; wane is a defect in high grades.
- It is associated with the entry of red-rot.
- It causes difficulty at the tree center where much of the high-grade lumber in small trees is found.

Ostrander and Stoltenberg (1957) estimate that for each observed weevil injury in a log there is a loss in potential lumber of from $2 to $6 per thousand board-feet. This estimate is probably conservative.

In summary, the factors that lower or raise lumber grade are known. The effect of the major degraders (knots and rot) can be reduced by proper forest management. The maintenance and expansion of the white pine industry is possible and practical if forest landowners use existing or new knowledge of the quality factors to guide their timber-growing and harvesting practices.

Volume Growth & Quality

by Richard D. Lane

THE preceding paper has given us an encouraging market outlook for white pine if we can meet the challenge of producing high-quality trees in sufficient quantity. What are the prospects for increasing white pine production and quality in the Northeast?

VOLUME AND GROWTH

About 5 million of the 73 million acres of commercial forest land in the 12 Northeastern States is in red and white pines, according to TIMBER RESOURCES FOR AMERICA'S FUTURE (U. S. Forest Service 1958). The same source gives estimates of volume and growth of red and white pines combined for this territory.

The volume in live sawtimber trees 9.0 inches d.b.h. and larger is about 11 billion board-feet. The total white and red pine growing stock in trees 5.0 inches and larger is estimated as 47 million cords.

Annual net growth of pine sawtimber in pine types is approximately 85 board-feet per acre. Total pine sawtimber growth in the Northeast is about 0.4 billion board-feet. By comparing this with the estimated current production of 0.75 billion board-feet one can easily see that we will be hard put to maintain our present white pine market position, let alone improve it. While these estimates are not precise, they can at least be considered indicative of the present situation and future prospects.

Total growing stock of red and white pines is increasing (before timber cut but after mortality) about 25 cubic feet per acre annually in the Northeast. Not all of this, of course, is on sawtimber trees.

These estimates of current growth do not reflect the growth that is possible with white pine, even in unmanaged stands. Normal mean annual yields for white pine in New Hampshire have been given as 110 cubic feet per acre on poor sites and 155 cubic feet per acre on good sites (Frothingham 1914). Similar mean annual yields have been reported from the Lake States. DeLong (1955) reported mean annual increments from 76 to 224 cubic feet per acre for 55-year-old Pennsylvania plantings with a 4 x 4-foot spacing. Baldwin (1949) reported a current annual growth of over 1,000 board-feet per acre for some New Hampshire plantations. Mean annual increments of 600 to 800 board-feet per acre are not uncommon in managed stands.

QUALITY

There are no valid estimates of the quality of our standing white pine timber. However, Lockard has already stated that the poor grade-pattern of white pine is well known. And, at the 1958 annual meeting of the New England Section, Society of American Foresters, Peter Koch stated that 55 percent of white pine lumber goes on the market as No. 4 and No. 5 Common (Wilson 1958). The diameter distribution of the standing timber can also give us some idea of its quality. In red and white pine sawtimber, only 20 percent of the volume is in trees 19 inches d.b.h. and larger. About 55 percent of the volume is in trees below 15 inches d.b.h. (U. S. Forest Service 1958).

Thus, it seems safe to assume that the quality of white pine in the Northeast is low. But, like growth, the current low quality of the resource does not reflect the full potential. The intrinsic quality of the wood is high and, by management practices, it is relatively easy to produce trees in which the quality-regulating features are prominent and the degrading features are reduced to a satisfactory low.

Conclusion: The Objectives

by Charles R. Lockard & Richard D. Lane

PRESENT markets and the prospect for a sustained heavy product demand lead to the conclusion that white pine management can be a promising business if its goal is quantity production of high-quality sawtimber. And timber quality as well as growth can be controlled in large measure by forest management.

Comparison of the potential market with the present quality and growth of our white pine resource leaves no doubt that the improvement and expansion of white pine management is a real challenge to all those who have a real interest in this resource, be they landowners, lumbermen, merchandisers, or public forestry officials.

It should be emphasized that the market available to us is not a fixed thing. It can be maintained only by the rigorous efforts of those concerned to increase sharply the volume and quality of white pine production.

II The Biological Bases for White Pine Management

What Is a Quality Tree?

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by Richard D. Lane

THE first part of this symposium has clearly pointed out that the most attractive white pine management objective is the rapid production of high-quality lumber. The quality characteristics of white pine lumber were briefly discussed. Since the forest manager deals with trees, not lumber, he must answer two questions if he is to use his management efforts most effectively:

- What kind of tree has the greatest growth of quality lumber?
- What environmental factors affect the production of such trees?

A complete answer to the first question requires the ability to identify the lumber-grading factors in the tree consistently and to evaluate them accurately. We do not yet have the ability, but the white pine log grades being developed by the Station will be a long step in this direction.

A complete answer to the second question requires a thorough knowledge of the whole complex of environment so that real causes can be distinguished from apparent ones.

We are reasonably certain of the role of some, but not all, environmental factors. Current site-growth studies at the Station will help give a better answer to this question.

In spite of these shortcomings we can give useful answers to the questions. What then, is a quality tree?

A STRAIGHT,, SINGLE-STEMMED, ROT-FREE TREE

In straight, single-stemmed trees there is no loss of merchantable volume from crooks, sweeps, or forks, and there will be a minimum loss of quality because of compression wood. If the trees are also rot-free, there will be no loss of volume or quality from this cause.

Stands in which all or most of the trees have these desirable characteristics may be developed by adequate protection practices in the silviculture and management program, combined with a continual culling of the growing stock to eliminate undesirable trees. Protection must include practices that prevent or hold down damage from fire, insects, diseases, and animals.

GOOD KNOT CHARACTERISTICS

Trees in which knots are limited in occurrence and distribution, and in which most of the knots are small, sound, red, and tight, will have a large part of their board-foot volume in potentially high-quality material. In particular, there will be few No. 4 and No. 5 Common boards.

These properties are developed in the tree primarily by proper pruning. Maintenance of the right stocking level or stand density may help reduce the costs of pruning but it will not, by itself, produce trees with good knot characteristics. Here are some facts about branch characteristics of trees in pure even-aged white pine stands (Paul 1938):

- There often are as many as 85 branches on the first 20 feet of a pine pole--the number varies with site quality.
- Lateral branches stay alive on the lower 20 feet of the bole an average of 15 years; dead branches persist for an average of 27 years, may last as long as 80 years.
- The knots from these branches range from 0.1 inch to about 3 inches in diameter; average is about 0.4 inch.
- Rapidity of crown closure, stand density, and stand composition have some effect upon the life and size of branches, but have no measurable effect on the rate of natural pruning.

Thus artificial pruning is the surest way to improve the knot characteristics of white pine trees and, consequently, their quality potential.

LONG INTERNODES

Trees with long internodes have fewer branches per foot of bole and therefore produce larger volumes of clear lumber. In addition, valuable clear cuttings may be obtained even from the knotty portions of the stem and thus raise the total grade yield.

Internode length is a function of site quality, crown class, and tree age at the time the internode is formed. Therefore, we can exert some control on internodal length by careful selection of the sites on which we will grow pine, and by cultural practices designed to maintain crop trees in the upper crown classes, particularly during the period of rapid height growth.

RAPID BUT UNIFORM DIAMETER GROWTH

A tree that increases rapidly in diameter will produce a given size and quantity of products in a shorter time than a tree that grows more slowly. Neither rate nor uniformity of diameter growth are recognized as quality determinants in lumber grades, but indirectly uniformity of ring width creates some improvement of quality by improving appearance, reducing the number and severity of drying defects, and improving in-service performance of the lumber.

It has been shown repeatedly that volume growth of a tree is proportional to crown size or some function of crown size. Burger (1930) showed that about 1 gram (fresh weight) of needles is required to produce 1 cubic centimeter of white pine wood in a year. An analogous relationship is that of diameter growth with the ratio of crown surface to bole surface. We have found in our current studies that about 50 percent of the variance in periodic diameter growth is explained by this ratio. Variations in site quality, in tree age, and in growing space (relative to crown size) may explain part of the residual 50 percent of diameter-growth variance.

The ratio of crown surface to bole surface is closely related to stand density and to relative crown positions of the trees. Consequently the rate of diameter growth is subject to considerable control through the control of growing space. If the crown is allowed to expand at the same rate as the bole, the rate of diameter growth should be uniform or nearly so.

Our studies have also shown that the ratio of live crown length to total tree height (expressed as a percentage) is nearly as good an indicator of diameter growth as the ratio of crown surface to bole surface--at least among dominant and codominant trees. Live crown ratio explained 42 percent of diameter growth variance in the studies we are making. Average 10-year diameter growth of dominant and codominant trees increases about 0.4 inch for each 10 percent increase in average live crown ratio. Similar--in fact, remarkably consistent--results have been obtained in central Maine (Davis 1958), Ontario (Smithers 1954), and western North Carolina (Wahlenberg 1955). Over a wide range of sites, ages, and stand conditions, the average 10-year diameter growth of trees with a 40 percent live-crown ratio appears to be about 1.5 inches.

GOOD BOLE FORM

In a tree with good bole form, the sawlog portion of the bole approaches the cylinder as the ideal form. It is round in cross-section and has a minimum of taper. Such trees yield the greatest proportion of their cubic-foot content in lumber, offer the greatest opportunity for the production of long wide boards, and permit maximum recovery of the valuable clear wood near the bark of the tree.

Bole taper appears to be controlled primarily by the form and position of the crown. Gevorkiantz and Hosley (1929) found that form quotient of white pine increased with increases in both the live-crown ratio and in crown width relative to bole diameter. In other words, among trees with a crown of a given size, taper will be less if the crown is short and wide, than if it were long and narrow.

Since crown width and crown length are closely related to growing space, it appears that we can reduce taper by cultural measures that give the tree the right amount of growing space. Artificial pruning of green limbs may also be a necessary part of this cultural control.

GENETIC CONTROL OF QUALITY

Ernst J. Schreiner has stated: "Forest genetics is merely one of the sciences essential to the successful application of the art of silviculture. Forest genetics, per se, cannot produce high-quality timber because of the many quality characters that are highly susceptible to environmental modification. For quality production, it will be necessary to control environmental factors as closely as possible through appropriate silvicultural practices."

Some of the quality-regulating characteristics that are heritable and subject to some genetic control are growth

rates, stem form, and branching habit. There is some evidence that resistance to pests also can be improved through genetics (Hirt 1948, Wright & Gabriel 1959).

SUMMARY

An examination of quality features of white pine trees and their relation to environment and management practices leads to the conclusion that through protection, site selection, stocking control, and artificial pruning we have or will soon have the means to produce just the kind of tree we want in the shortest possible time.

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Effect of Site & Stocking on Quality Growth

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by Robert W. Wilson

IF we are to use site selection and stocking control in producing high-quality white pine, we must know how to recognize site quality. We must also know how site and stocking affect quality growth.

SITE QUALITY APPRAISAL

Height of dominant and codominant trees, in relation to their age, is the most commonly used measure of site quality. When referred to a standard age through curves of height over age prepared for that purpose, it is called site index. Several sets of site-index curves are available for white pine (Barrett 1934, Frothingham 1914, Gevorkiantz & Zon 1930, Husch 1954, McCormack 1956, Spurr 1952). When a site is occupied by an even-aged white pine stand more than about 30 years old, its quality can be estimated by the appropriate height and age measurements. Damage by the white-pine weevil to tree leaders undoubtedly has some effect on the reliability of these estimates, but apparently the effect is not very great (Husch & Lyford 1956).

When stands suitable for direct estimation of white pine site index are not present, other means must be used. As the result of work recently completed by Ralph Foster (1959) in western New England and eastern New Hampshire, site quality for white pine can now be estimated from red maple site index. He expressed the relationship between the site indices for these two species in a prediction equation. Prediction is improved a little if aspect is added as an independent variable. Foster also concluded that site quality for white pine was governed by the moisture relations of the site as expressed by as many as five individual site features.

A number of other investigators have sought to evaluate the relation between the height or site index of white pine and certain combinations of site features. Investigations of this kind provide the basis for estimating site quality from the site itself, regardless of existing vegetation.

In southeastern New Hampshire, height of dominant and codominant white pines has been shown to increase with increased age, decreased natural drainage, and increased stand density (Husch & Lyford 1956). The significance of stand density may result from its relation with stand age and with site features that affect both height growth and stand density (or carrying capacity) of the site.

Comparable results have been obtained in central Massachusetts where Spurr (1952) described five site classes by the kind of parent material (primarily reflecting origin and coarseness of the particles) and the depth to the water table. Poor sites are either very dry (such as many of the Hinckley, Merrimac, and Japprey outwash soils), or very wet. Medium sites are glacial tills (relatively fine-textured) with low to medium-depth water tables, such as the Charlton, Brookfield, and Gloucester soils. The best sites are glacial tills with high water tables and moderate to imperfect drainage such as the Acton and Sutton soils. Similar results have also been obtained in the Lake States (Roe 1935).

In Maine and the Central States the thickness and texture of the A and B soil horizons have been used in several combinations and modes of expression to estimate site quality (Young 1954, Czapowskyj 1957, Gaiser & Merz 1953). Generally, site quality improves with increased depth and finer textures of the horizons.

Thus, we have a number of site studies, each apparently expressing a basic soil-moisture/parent-material relationship with site quality in a slightly different way; and each applicable only in one locality. One of the objectives of the Station's white pine management program is to supplement these findings with additional field work in order to develop a site-estimation scheme with regional application.

SITE AND STOCKING IN RELATION TO QUALITY GROWTH

In the previous paper, site or stocking or both were considered to have some effect on internode length, diameter growth, tree form, and character of knots. Available information on a number of these relations is at best fragmentary and indirect, but all that we have substantiates Lane's conclusions.

Height growth, and therefore internode length, of dominant trees is greatest between the ages of 10 and 40 years, approximately. During this period it may be twice as great on the best sites as on the poorest ones (Frothingham 1914). Average internode length of trees that are dominant between these ages is 1.8 feet on the best sites, but it is not uncommon for internodes up to 4 feet long to occur. Internode length is, of course, less in the trees of the lower crown classes than in dominant trees. Internode length appears to be independent of stocking level (Tarbox & Reed 1924, Hawley 1936), despite the apparent relation observed by Husch and Lyford.

Reports of increased diameter growth after thinning to reduce stocking in white pine are too numerous to mention. The relation between stocking and diameter growth is quite generally accepted. However, the effectiveness of a thinning depends not so much on the amount of stocking left in the stand as on the degree to which the competition among the remaining trees is relieved (Adams & Chapman 1942, Smithers 1954).

In general, white pine stands have been thinned lightly and from below--taking out the smallest and lowest-crown-class trees first. Dominant trees show little or no response to such thinnings but response among the lower crown classes is progressively greater from the codominants to the intermediates. In a number of tests where both crown thinnings and thinnings from below were used, Smithers observed that some trees of all crown classes responded well to thinning while others responded poorly, depending upon how much of their competition had been removed.

The effect of site quality on diameter growth is not so clear-cut. It appears to be much less marked than the effect of stocking; yet normal yield tables show definite increases in average stand diameter with site quality, despite accompanying increases in normal stocking. Average diameter of the 50 largest trees per acre (the trees least influenced by stocking level) has been shown to increase with site quality (McCormack 1956) and, with the effect of stocking held constant, average diameter of dominant and codominant trees was shown to increase with decreasing natural drainage--an inverse expression of site quality (Husch & Lyford 1956).

Very little is known about the effect of site and stocking on form of white pine beyond the general observation that it is better in dense than open stands. Behre (1932) suggests that form improves after thinning. Observations by Gevorkiantz and Hosley (1929) and Bedell (1948) suggest that, as stands become overly dense, form class decreases. The good form of the famous "punkin" pines of the past was apparently the result of strong competition during the first 50 years or so, followed by complete freedom to grow (Foster 1957).

When crowns have closed by the time a white pine stand is 20 years old, the size of knots in the first log is inversely proportional to the number of trees per acre (Tarbox & Reed 1924). Quality of the timber yield from pure stands depends upon the time required to complete crown closure. Tarbox and Reed also found that species composition is an important stocking element in the production of quality timber. The highest quality of lumber is produced from pine-hemlock stands in which the pine was partially suppressed through the first 40 to 50 years of life. The quality of lumber produced from a well-stocked pine-hardwood stand is better than that obtained from most pure pine stands. However, mixed stands of ordinary density do not produce as good quality lumber as do dense pure pine stands.

Gevorkiantz and Hosley (1929) used the ratio of relative dead length to crown width as a measure of the growing space available to a tree throughout its life. They concluded that when this growing space was large, branch size was large, and rate of natural pruning was low in comparison to small growing space.

SITE AND STOCKING IN RELATION TO STAND VOLUME GROWTH

Normal white pine yield tables developed for New Hampshire (Frothingham 1914) and the Lake States (Gevorkiantz & Zon 1930) give volume of normally stocked white pine stands by site and age classes. These tables give us an estimate of the normal stocking or carrying capacity of the site in terms of basal area. They also make possible an estimate of the net volume-growth potential of the site. However, they are not very useful as direct guides to silviculture and management practice because they do not consider the quality of the growth nor do they permit estimates of growth at other stocking levels.

On the best sites (site index 75) normal stocking is roughly 250 square feet of basal area per acre at 50 years and about 310 square feet at 100 years. On the poorest sites covered by both yield tables (site index 55) normal stocking is about 200 square feet at 50 years and about 250

square feet at 100 years. The corresponding net yields are 8,400 and 14,900 cubic feet on the best sites, 5,100 and 10,100 cubic feet on the poorer sites.

Probably the best available analysis of per-acre growth relations is that made by Smithers (1954) with data from natural red and white pine stands at the Petawawa Forest Experiment Station, Ontario. Periodic measurements of a number of thinning experiments carried on over periods up to 30 years were available. The soils on which the stands grow are coarse-textured outwash and water-washed tills; the site quality is lower than that typical of northeastern United States. Site index ranges from about 43 to about 55 feet at 50 years total age. Normal stocking or carrying capacity also appears to be less than that given by our normal yield tables.

In unthinned stands, Smithers found that basal area per acre increased very little after the stand reached 50 to 55 years of age. This maximum stocking or carrying capacity was about 220 square feet on the best sites (site index 55) and about 140 square feet on the poorest sites (site index 40). Gross periodic basal-area increment varied with stand age and site quality. In fully stocked stands the greatest gross periodic basal-area increment occurs at about 25 years of age and is 7+ square feet per acre annually on the best sites (site index 55) and 5 square feet per acre annually on the poorest. At 80 years of age, increment drops to 2.4 and 1.2 square feet per acre annually on the best and poorest sites, respectively.

Basal area per acre seemed to have little effect on gross basal-area growth. However, there was a great deal of variation from plot to plot. Smithers expressed both increment and stocking level as percentages of normal and compared the values with those to be expected if the thinning distribution had been as poor as possible--a portion of the plot clearcut, the remainder uncut. He concluded that if thinnings are well distributed, it may be possible to carry a stocking 70 percent of normal without sacrifice in gross basal-area increment.

Among these plots, current annual net increment and net yields plus thinnings were consistently greater on the thinned than on the unthinned plots. Gross yield, including mortality, was little affected by thinning in most cases. The same relationships held for board-foot volume.

A further analysis of the plot data given by Smithers reveals that periodic net cubic-foot increment decreases with age and increases with site quality but is unaffected by stand density. Site quality is the more important variable in explaining cubic-foot increment. Board-foot net periodic increment is influenced by all three independent variables. Site quality is the most important variable, followed by stand density.

SUMMARY

From information now available it is possible to draw some general conclusions about the relation of site and stocking to the growth of quality sawtimber:

- The best sites produce not only the greatest growth of timber but the best quality timber--other things being equal.
- A substantial reduction of stocking below the normal level is possible without loss of per-acre volume growth.
- Stocking level, in itself, has limited influence on quality growth. Internode length is not affected by stocking level. Branch size is smaller and rate of natural pruning is greater at high than at low stocking levels but the differences in terms of timber quality are not very great. Average diameter growth is less in high-stocked than in low-stocked stands.

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Effect of Site & Stocking on Reproduction

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by William E. McQuilkin

SITE in the strictly physical sense refers to the conditions on an area that derive from the soil and its location with respect to slope, aspect, altitude, and regional climate. Closely associated, and comprising an integral part of site in the broad sense, are biologic factors, of which plant cover usually is the most obvious and often has the most influence upon tree reproduction. In these remarks the term site is used in the physical sense, and stocking refers to the plant cover on a physical site.

Site and stocking profoundly affect the establishment of white pine reproduction, its survival and growth through the seedling-sapling period, and the species composition of young stands developing after logging, fire, or agricultural use. The effects of site and stocking upon growth of trees and stands beyond the sapling stages have been discussed by Wilson in the preceding paper.

ESTABLISHMENT OF REPRODUCTION

Assuming the presence of seed or planted seedlings, and location within the natural range of white pine, site and stocking affect the fate of white pine reproduction largely through three basic silvical or ecological factors: surface soil temperature, soil moisture, and light.

Surface Soil Temperature

Surface soil temperatures are of greatest concern in establishing white pine directly from seed. It has been known from the time of Toumey's studies that surface soil temperatures in the open commonly become high enough to cause mortality of newly germinated white pine seedlings (Toumey & Neethling 1924). David Smith (1951) cites Lorenz (1939) in placing the threshold of heat injury at 131°F. Seedlings are most vulnerable immediately after emergence; by mid and late summer the danger of heat mortality is practically over.

The composition and color of the surface material have considerable effect upon the build-up of heat. The black surface of recent burns is very conducive to high temperatures. Pine litter becomes one of the hottest surfaces when exposed to full sun; in fact, pine seedlings rarely survive on fully exposed pine litter unless the specific microsite of a seedling receives some mid-day shade, as from a rock, a fragment of wood, or another plant. Moss mats, particularly of Polytrichum moss, are among the coolest and most favorable seedbeds for white pine. Mineral soil falls in between.

Obviously surface soil temperatures are important to seedling survival only in spots or areas that receive full mid-day sun. Vegetation of any sort that will shade the ground ameliorates the condition, and reduces the importance of seed-bed material. The shade of a shelterwood enables seedlings to start and survive even on pine-litter seedbeds.

Mineral soil, when dry and in the open, can build up lethal temperatures, but it is a favorable seedbed if moist or lightly shaded. Since it does not dry out so quickly as pine litter, seedlings on mineral soil even in the open have a fair chance to survive the crucial weeks immediately after emergence. Where excessive stocking to undesirable brushy or herbaceous plants necessitates site preparation with earth-moving equipment, exposure of mineral soil is a normal consequence. Despite some danger from heat injury, creation of a mineral-soil seedbed in such areas usually is the most practicable measure that we can take to favor natural white pine regeneration. If the site treatment can be manipulated to leave a scattered or sparse plant cover to provide some shade, so much the better.

Physical site properties affect the likelihood of lethal surface temperatures occurring in exposed mineral-soil seedbeds. Soil texture affects water-holding capacity: sandy soils dry out faster than finer textured ones, and thus are more subject to heating. Position on a slope and aspect affect moisture relations: upper slopes and southerly or westerly aspects dry quicker and to greater degree than the opposite positions, again predisposing to surface-soil heating.

Soil Moisture and Light

Since both soil moisture and light are much influenced by plant cover, and can most readily be modified by manipulations of the cover, they may be considered together. All types of cover, from low herbs to tall trees, use and compete for soil moisture, and all except the lowest herbs reduce the light available to small pine seedlings. In general, light is the more crucial factor affecting seedling survival. Moisture deficiencies may account for considerable mortality in the immediate post-emergence period, and in open spots may predispose to heat injury; but thereafter its effects are manifested more in reduced growth than in outright mortality. In nature, however, without the helping hand of man or the destructive action of fire or windthrow, the vast majority of the pine seedlings that germinate do not get enough light to survive. White pine seedlings require as a minimum about 20 percent of full natural light to survive and grow enough to maintain themselves from year to year (Shirley 1945).

So, to provide conditions favorable for white pine regeneration, we must work largely with the plant cover. In forest stands, we open the canopy by shelterwood, patch, or strip cuttings, and as necessary control the understory and ground cover with chemicals (Foster 1954) or by such treatments as disking. In brushlands or heavy sod, we reduce the cover with earth-moving equipment or, in some situations, with chemicals. Bearing in mind that, for regeneration from seed, some shade is desirable, the aim in all such operations should be to reduce and control the cover, but not to eliminate it. Such control results in conditions that minimize heat injury, reduce the competition for soil moisture, and give the pine seedlings--whether natural or planted--adequate light for good growth.

JUVENILE SURVIVAL AND GROWTH

With a catch of white pine seedlings--natural or planted--on the ground, site and stocking continue to affect their growth through the basic factors of soil moisture and light. The physical site--soil texture, topographic posi-

tion, aspect, etc.--affects moisture relations directly; also, indirectly, it affects both soil moisture and light through its relationships to the stocking, growth rates, and composition of the associated plant cover.

In general, hardwood species become established in greater numbers and grow much more vigorously on heavier, moister soils than on the sandier soils and drier sites. Ecological and weeding studies show conclusively that the relative capacity of white pine to compete varies with site quality: it competes relatively better on the sandier or drier sites. Because the hardwoods do poorly on these sites, substantial numbers of white pine seedlings can get enough light to become established and to continue to grow, eventually overtopping the hardwoods and becoming dominant. On the sites where hardwoods thrive better, any white pine seedlings that may start are mostly shaded out in the seedling or small-sapling stages.

These differing species characteristics thus result, under natural competition, in white pine being restricted largely to the sandier, drier sites. This has given rise to the concepts of "white pine sites" and "permanent white pine types." A white pine site in this sense means little more than that it is a poor site for hardwoods. In their physical attributes, such sites are mostly only mediocre for pine growth.

White pine, if free from suppression, actually grows best on the so-called "hardwood sites"; i.e., it responds to the same site factors that favor hardwoods. It is generally absent from such sites because, under natural competition, the hardwoods respond with even greater vigor. Where site quality falls between definitely good and definitely poor for hardwoods, pines and hardwoods during the seedling-sapling period tend to compete on more nearly equal terms, and pine-hardwood stands commonly result. Except where natural trends are upset by cuttings, fire, or other disturbance, the better the site, the fewer the pines that will survive to enter into the later stages of the stand.

Insect Damage & Control

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by Raymond C. Brown

EASTERN white pine is known host to nearly 50 insect species (Craighead 1950) including root, bark, and leaf feeders; bark, phloem, wood, twig and cone borers; and sucking insects that infest all parts of the tree. Most of these cause relatively little timber damage in the forest. A few cause real damage when they reach epidemic levels. Three can be rated as very destructive insects: the cone beetle, the pales weevil, and the white-pine weevil.

Each is a native insect in North America. Each carries an enormous potential for the destruction of white pine timber values. And each is nearly always present in sufficient numbers to cause substantial damage. While none of them threatens the existence of white pine as a species, they do, in combination, seriously restrict reproduction and reduce volume and quality of white pine timber crops. It is interesting to contemplate what white pine management might accomplish in the absence of these three insects.

ROLE OF CONE BEETLE

The destructive power of the cone beetle has been dramatically demonstrated on the Massabesic Experimental Forest at Alfred, Maine, where, except for a light seed crop in 1954, virtually no seed has matured in 7 years. Observations during the last three of those years have established that good crops of cones were set every year but nearly all cones were destroyed in their second season by the cone beetle.

No region-wide survey has been conducted to determine the extent of damage, for as yet no practical method has been devised to make such an appraisal. However, it is known that the cone beetle occurs throughout the natural range of white pine and that it is capable of completely destroying the seed crop in some areas in certain years.

Forest entomologists in general have shied away from cone insects, probably because it is not easy to study an insect at the top of a seed-producing tree. Consequently, we lack information on the biology and habits of the white-pine cone beetle.

The adult beetles apparently hibernate in infested cones that fall to the ground prior to maturation. In the early spring the beetles emerge from the dead cones and attack living second-year cones. The beetles mine down the

axis of the cones and kill them. Eggs are laid in the infested cones, and the beetle grubs feed on scales and seed. Development is completed in the cone.

Efforts to control the cone beetle have not been encouraging. In 1956 a number of insecticides were applied to a few trees with a mist blower. The results looked promising. In 1957 the two best materials were applied in early spring by helicopter to 10-acre plots on the Massabesic Forest. Protection from beetle attack was apparently obtained for a few weeks, but by August all cones on pines in the sprayed plots were infested. It must be concluded from these tests that more information on the biology and habits of the insect is needed to obtain control, either by chemical or other means.

ROLE OF PALES WEEVIL

The pales weevil is responsible for heavy losses of white pine seedlings on recently cut-over pine lands. No estimates of statewide or regional losses have been made, but foresters and entomologists have often observed nearly complete mortality of seedlings established after the cutting of a pine stand. When pine is planted right after a cutting operation, total loss of the planted stock is the usual result.

The losses are the result of stem-girdling by the adult weevil. Adults over-winter in the litter. They emerge in the spring and feed on the tender bark of sapling twigs and at the bases of small seedlings. Eggs are laid in the inner bark of freshly cut pine logs and stumps. A new crop of adults appears in September.

The most severe damage to seedling pines is caused by this second generation. They feed mostly at night; by day they feed below the surface of the litter. The first evidence of damage is the wilted seedlings. Then it is too late for control measures.

Several means are available for protecting seedlings from attack. One is to delay planting or other regeneration treatments until the insect population has subsided. Cut-over areas may be safely planted the second or third season after cutting. Bundled seedling may be dipped in lead arsenate suspensions, or emulsions of DDT or benzene hexachloride, taking care that the roots do not come in contact with the chemical. Or, seedlings may be sprayed after they have been planted (Potts 1955).

ROLE OF WHITE-PINE WEEVIL

The great reduction of white pine timber volume and quality associated with stem crooks and forks is common

knowledge among people dealing with the species. Much of this loss is caused by the white-pine weevil, which in the opinion of many is the most serious forest insect pest in the Northeast. How great the loss has been is partially documented by the results of a study of white pine plots in New Hampshire (Waters et al 1955). In that state, the total standing volume is an estimated 13 percent less in pole-timber trees and an estimated 40 percent less in the saw-timber portion of sawtimber trees than it would have been had trees not been damaged by the weevil. And the situation is all the more serious because there is still no fully effective and practical way to control the weevil under all conditions.

Trees become susceptible to attack when they reach a height of about 3 feet and remain susceptible thereafter. The leader, and often one or two previous year's growth, is killed by the feeding of many larvae under the bark. Subsequently, one or more side branches assume dominance, and a crooked or forked tree results.

Eggs are laid in early spring by adults that emerge from the duff where they overwinter. Thus damage can be prevented by killing the weevil adults before eggs are laid.

This can be accomplished by thoroughly spraying the leaders in early spring prior to egg-laying (Crosby 1954). A number of chemicals are effective and it has been found that some applied in the fall are effective the following spring (Crosby 1958). But to obtain the thorough coverage required for complete control, the spray must be applied with knapsack sprayers and this restricts treatment to small trees. Even with an extension rod attached to the sprayer, treatment is limited to trees no more than 12 feet tall.

Exhaustive tests with aircraft, using high dosages of many insecticides, have been made (Connola et al 1955). A test conducted in 1957 using 4 pounds of DDT in 4 gallons of spray per acre applied by airplane failed to give satisfactory control. Helicopters have given better results than fixed-wing planes. Ninety-eight percent control has been obtained in some tests. But the problem in aerial-spray application is to consistently obtain thorough coverage of the leader.

Control of the weevil through silvicultural practices may be a possibility, for it is common knowledge that weevil attack is less severe on white pines growing in mixture with hardwoods that overtop them than on open-grown pines. The problem, therefore, is to create, through silvicultural methods, just the right amount of overtopping to inhibit weevil attack and still permit satisfactory growth of pine.

Disease Damage & Control

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by Marvin E. Fowler

WHITE pines may be killed or rotted, or both, by diseases that attack the living trees. Some diseases of white pine produce external symptoms that are readily noticed, but many others are often obscure to the unpracticed observer. Knowledge of disease behavior is essential to the development of sound control practices. Our first line of attack against diseases should be to prevent conditions that favor them and to recognize and control potentially serious diseases before damage becomes widespread and serious.

WHITE PINE BLISTER RUST

White pine blister rust continues to be the principal disease threat to white pine. It will infect, and eventually kill, white pines at any age or stage of development. Even before the disease was introduced into this country it was widespread and had inflicted severe losses in eastern white pine plantations in western Europe. The life history of the fungus had been worked out and pathologists knew that the fungus could not spread from pine to pine but had to spread to ribes and from them to pine.

Thus, when the white pine blister rust was discovered on cultivated ribes in New York State a half century ago, its threat to our native white pine stands was immediately recognized. In 1915 a control program was initiated, based on the destruction of ribes in and near white pine stands. The continuing control program has given protection to our commercial white pine stands. There is no doubt that, without control, all of our ribes-inhabited commercial stands in the Northeast would be destroyed before they reached merchantable size.

Blister rust is insidious, and the greatest economic loss it can cause is not readily apparent. In areas where control measures have not been initiated, the rust usually kills so many seedlings and small saplings that it prevents the development of commercial stands. The more apparent losses of volume and quality from cankers and killed trees (much of which goes unsalvaged) is usually light and scattered. Only occasionally are heavy losses encountered in stands of merchantable size.

Consequently, regeneration and management of young white pine stands is practical only where ribes do not regenerate readily or where they are eradicated. In large

pole-sized stands, management is practical in regard to blister rust whether the ribes are eradicated or not. In fact, the opportunity to remove diseased and killed trees in improvement and salvage cuts can reduce rust-caused loss in stands of this kind.

Blister rust control measures have worked well in most areas and have provided the protection desired. But in some localities control is hampered by environmental conditions that favor the development and spread of the rust. Fog, humidity, temperature, and prevailing wind all affect rust behavior. For instance, areas where fog settles favor rust spread more than nearby higher ground. Research on these effects of climate and micro-climate is being conducted in the Lake States and the West; and the results will no doubt apply, at least partly, in the Northeast.

For many years pathologists and foresters have looked for a native white pine that is resistant to blister rust. A number of pines have been selected for resistance and are being field-tested. In one test the Station is cooperating with the New York State University College of Forestry at Syracuse. Selected trees are outplanted and rust-infected ribes are grown between the rows of pine. Infected pines are allowed to die and the others are kept under observation.

CANKERS AND DIEBACKS

In addition to white pine blister rust there are a half dozen other fungi that cause cankers on the main stems of white pine. Some of these will occasionally girdle and kill the trees, but the damage consists mostly of degrade and of storm breakage that is increased by the weakening effect of the cankers. The best known stem cankers are those caused by *Phomopsis, Atropellus,* and *Tympanis.*

Two dieback fungi, a *Diplodia* and a *Cenangium,* sometimes cause damage to white pine. The tree crop is not threatened by them, but losses in restricted areas are sometimes severe.

Both canker and dieback diseases are most damaging on trees of low vigor. Thus the establishment of plantations and the favoring of natural reproduction on good sites, proper control of stand density, and other practices that result in vigorous growing stock, will do much in minimizing these disease losses.

WOOD DECAY

Decays of heart and sapwood greatly reduce timber quality and volume. In old-growth white pine decay is be-

lieved to amount to more than 20 percent of the volume. There is no reliable estimate of the additional loss in quality. In a large sample in Ontario, it was found that 40 percent of the 60-year age class white pines contained decay (White 1953). This percentage increased with age to the 220-year age class in which all of the trees had some decay.

Over 30 species of fungi are known to cause rot in living or dead white pine in the Northeast. In the living tree the fungi enter through some abnormal opening. Broken stems, scars from logging operations and from fires, ax blazes, attacks by insects, and natural pruning of large branches cause such openings.

The most common of the heart-rotting fungi, red ring rot *(Fomes pini)*, causes large losses of timber volume and, in its incipient stages, causes degrade of an additional large volume of lumber. It frequently enters the tree through leaders killed by the white-pine weevil so that, in effect, this insect is a double hazard in the management of white pine for quality sawtimber.

Prevention of injury to living trees will greatly reduce rot losses. Butt-rot losses are reduced through fire protection and greater care in logging. Trunk rots are reduced through avoiding logging damage, removal of rot-risk trees in partial cuts, making salvage cuts in badly damaged stands, judicious pruning, and adjusting the rotation age so as to harvest the trees before the rot increase offsets the growth increment.

ROOT ROTS

Disease losses in white pine plantations have increased in recent years. *Fomes annosus*, a butt- and root-rot fungus, is becoming increasingly important. The root disease caused by this fungus has not been important in natural stands, but losses are increasing in older coniferous plantations. The fungus builds up and spreads as freshly cut stumps become infected following thinning operations. Once the fungus spreads through the roots of the cut trees it can spread into adjacent living trees when their roots come into contact with the diseased roots. Enlarging pockets of dead trees result.

Fomes annosus root rot is already a serious problem in coniferous plantations in New Jersey, New York, and the New England States, especially on red pine. It is present in several white pine plantations, and while losses have not been severe, the threat is very real. This fungus is reported to be responsible for 90 percent of the decay in conifers in Great Britain. We are currently testing the effectiveness of applying creosote to freshly cut stumps in

thinned plantations. British pathologists have recommended this procedure as an effective control.

The shoe string fungus, *Armillaria mellea,* and *Phytophthora* root rot also cause losses of white pine. The former is particularly severe on trees of low vigor and the latter on trees growing on wet sites. Proper site selection and maintenance of tree vigor are the best ways of combatting losses from these diseases.

FOLIAGE DISEASES

The diseases that attack the foliage of white pine cause an undetermined amount of damage. Infected trees are seldom killed, but their vigor and rate of growth are affected. Trees of low vigor become more susceptible to other diseases and evaluation of the importance of the needle diseases becomes more complicated.

White pine is susceptible to a number of needle fungi. The more common are species of *Septoria, Phacidium, Bisfusella,* and *Hypoderma.*

In addition to the needle diseases of known cause there is through much of the Northeast a general decline of white pine from an unknown cause. The condition is particularly severe locally, from Massachusetts to Maine. In this disease, the needles are chlorotic and short. The symptoms differ from the more commonly known white pine needle blight (also from an unknown cause) in which the current year's needles die from the tip to about half their length. While there is some thought that site and tree vigor may be associated with this decline, we cannot recommend practices to effect control.

CONCLUSION

Intensive surveys are necessary to obtain precise data on the magnitude of the impact of diseases of eastern white pine. By such means more accurate estimates of future timber yields could be made, disease-research priorities established, and adequate disease control and related research needs determined.

We need to measure the disease losses caused by heart rots, root rots, cankers, and other major diseases. We need additional information on the behavior of disease organisms and on the conditions that affect their spread and intensification. We need more information on the effects of management practices on the occurrence and severity of diseases. In short, we need more research on the diseases of white pine that will lead to improved control measures. Every reduction in the disease loss, either in volume or in quality, will be a net gain to white pine forestry.

III White Pine Management for Quality Production

Evaluating Management Opportunities

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by Carl H. Stoltenberg

IN one way or another, the forester earns his bread and butter by being able to advise forest owners about forestry practices. And because owners want their funds used prudently, the forester is actually concerned with the relationship of management practice costs and the value of their results.

Thus from the forester's standpoint, the question "What's known about managing white pine?" might appropriately be phrased "In specific stands, what returns can be expected from specific investments to maintain pine, increase its growth rate, and improve its quality?"

This orientation places our knowledge of white pine management in a slightly different light. Several brief examples will illustrate the distinction.

INFORMATION NEEDED FOR INVESTMENT ANALYSES

We know that on the better sites (the heavier soils) pine will usually be competing with valuable hardwoods, and on the poorer sites with relatively low-value hardwoods. We know that it will take more effort per acre to keep pine in the mixture on the heavier soils; but on the other hand these good sites can grow pine faster--perhaps twice as fast as the poorer sites. Unfortunately, we don't know how the cost-per-thousand of growing pine varies with site conditions. Silvicides have put pine management of the better sites within the realm of possibility--but we don't yet know under what conditions their use is practical.

We know that trees in lightly stocked stands grow faster in diameter than trees in dense stands, and that thinning is a non-commercial venture in young stands. But we don't know in which stands thinning investments will pay off.

We know that clear pine logs are more valuable than knotty ones, and also that they cost more to produce. But we don't know whether the additional cost is warranted in view of future market prospects.

We know pine in dense stands develops clear boles faster than if it is open-grown. We also know that artificial pruning could achieve the clear bole without slowing the tree's growth. But we don't know whether the financial advantages lie with dense-stands-and-natural-pruning or with open-stands-and-artificial-pruning.

We know that white-pine weevil damage is serious and also that weevil-control costs are high. But we are just beginning to develop a sound basis for selecting those stands in which the costs of weevil control are less than the costs of weevil damage without control.[2]

We know that damage from the white-pine weevil is less when pine has an overstory of hardwood. But unfortunately this overstory slows the growth of the pine, increases the number of knots per log, and leaves the pine in a rust-susceptible stage longer. But our knowledge isn't good enough to identify those cases where the silvicultural form of weevil control would be more expensive than spraying. Or those where neither is justified.

Blister rust will eliminate pine under certain conditions--but in other stands losses are less, and in some stands they are negligible. A study now being completed by

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[2] Marty, Robert J., and Glen R. Allison, 'Assessing white-pine weevil control opportunities'. Unpublished manuscript, Northeast. Forest Expt. Sta., 1959.

the U. S. Forest Service will indicate what we can afford to spend protecting a given stand from blister rust. Unfortunately the present scope of this study is limited to white pine stands in the Lake States. Similar guides are not available for the Northeast.

In mixed stands on the lighter soils, we can reproduce pine naturally by several silvicultural systems. On the heavier soils (higher site indices) we can obtain pine regeneration by variations of the shelterwood system--although we expect difficulty from aggressive hardwoods. But can we, with any degree of confidence, select those stands in which it is worthwhile to go to the effort of obtaining pine reproduction?

QUANTIFICATION OF KNOWLEDGE IS ESSENTIAL

These examples indicate we know quite a bit about managing white pine. But in almost every case we are unable to answer the critical problem--or at least to provide a really convincing answer. When we get right down to it, we aren't able to compare the available alternatives. How can we compare the dollar cost of weevil-control-by-spraying with the growth loss of weevil-control-by-overtopping-hardwoods, for example? Actually we have the tools. The business man's yardstick of dollar values and costs is, in most cases, an adequate device.

The real problem lies in the form of our knowledge. We know trends; we know the general nature of relationships --but we lack quantitative data. We know which way--but we don't know how much. And the *how much* is absolutely essential if we are to evaluate alternatives.

Let me refer to one example in more detail. A fairly common situation in the pine region is to have a fairly well stocked stand of pine under an overstory of hardwoods. At least one decision must be made in such a situation--whether or not to remove the overstory to release the pine.

What to do about this situation?

We know that without release we may lose some of our pine stocking--but usually we don't know *how much*.

We know that *with* release weevil damage will probably be greater--but we don't know *how much* greater, or indeed *how much* the volume or value losses due to the weevil would be in either situation.

We know that release would increase the rate of pine growth--but we don't know *how much*.

Dealing with the pine and hardwoods in the same way, we know that the denser the stand, the slower individual tree diameter growth will be--but our quantitative knowledge of this relationship is limited.

Until we can enter a stand and have some idea of *how much* stocking would be saved by removing the overstory, and *how much* weevil damage would be increased and *how much* pine growth would be accelerated, we won't be of much help in deciding whether to release. And until we know, *quantitatively,* at least how much diameter growth will be accelerated by various degrees of thinning, we can't with any confidence recommend how heavily to thin--indeed whether to thin at all.

PROGRESS IN ATTEMPTING TO QUANTIFY KNOWLEDGE

To quantify some of these relationships, several good starts are being made. They include:

- A study to estimate the volume loss to be expected from weeviling of various intensities.
- A study to estimate the value loss due to lumber degrade from weeviling of various intensities.
- A study to determine the effect of stand density on the frequency and severity of weevil attack.
- A study to determine the effect of stand density and soil-site quality on pine growth rates.

Unfortunately most of these studies are operating on a modest scale, and to the best of my knowledge no one is working on the problem of growth or stocking losses from a hardwood overstory. But the region's forestry-research institutions are making definite progress.

SUMMARY

We have a good deal of raw knowledge regarding the growth of mixed stands of pine and hardwood. But to analyze managerial alternatives--to answer the really vital questions of management--we need to quantify the general knowledge we now have. Current knowledge is inadequate for efficient management. And this inadequacy is one of the most serious deterrents to intensive white-pine forestry in the Northeast.

But current knowledge *is* adequate to make research really pay off in terms of vital, usable results in a rela-

tively short time. Answers to the questions managers need are "just over the hill", so to speak. We know what we need; we know where and how to find the answers; but we have just begun searching for them.

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Establishing White Pine on Open Land

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by William E. McQuilkin

WHITE pine poses no special difficulties to establishment on open land. Given a seed supply, it usually will restock sparsely vegetated areas abundantly by natural seeding, as witnessed by the thousands of acres of old-field pine that developed over the past century throughout the Northeast as farm land was abandoned. In artificial regeneration, it offers no unusual production problems in the nursery, and it transplants easily to the field. The main obstacle to both natural and artificial regeneration is the widespread prevalence of field conditions that are unfavorable for seedling establishment and growth.

The open lands of today are mostly brushlands of one sort or another--cut-over or burned-over forest lands covered with hardwood sprouts, briars, shrubs, and ferns; or old pastures, still soddy in part, but invaded to varying degrees by hawthorn, hardhack, juniper, and other woody growth. Neither natural nor planted seedlings can develop into satisfactory stands in such situations. Fields recently abandoned from cultivation and occupied only by herbaceous plants usually are favorable for pine regeneration, but these make up only a small part of the total of open non-productive land in the Northeast. So, in most places, the essential first requirement for establishing white pine is adequate preparation of the site.

SITE PREPARATION

Elsewhere it has been pointed out that the basic silvical or ecological factors associated with site are surface soil temperature, soil moisture, and light. Site prep-

aration involves modifications of these factors through manipulations of the soil surface and the vegetation. The modifications may be accomplished by mechanical means such as tools or machines that cut or dig, by chemical herbicides or silvicides, or by fire. Fire as a controlled treatment for site preparation, though extensively used in the South, has not been used in white pine silviculture. Mechanical and chemical methods are discussed below.

Mechanical Methods

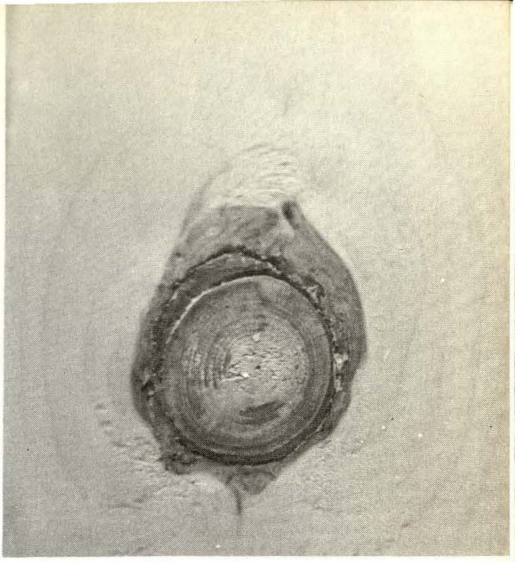
Mechanical methods involve the use of plows, disks, bulldozers, and root rakes. Some planting machines open a shallow furrow ahead of the planting shoe, or have scalper attachments, and thus do a kind of site preparation. On small jobs, site preparation may mean hand scalping of spots with a mattock or grub hoe.

Mechanical methods both reduce the competitive plant cover and provide a mineral soil surface; they clear the ground for planting, or prepare a seedbed for seed regeneration. In many situations a well-chosen mechanical treatment will result in an eminently satisfactory job.

The choice of method, however, may be important. For instance, one would apply some sort of broad treatment in preparation for natural seeding or artificial broadcast seeding, whereas a furrow might be adequate for planting. Also, method must be adapted to cover; heavy brush requires heavy equipment such as a bulldozer or root rake, whereas disks or light plows may work well, and at less cost, in lighter types of cover. However, some kinds of vegetation recover very quickly from treatments, like disking, that merely chew the plants to pieces. After a year or two, stoloniferous species like blueberry, sweetfern, meadowsweet, bracken fern, and quackgrass may be as competitive as before. For lasting effects, such species must be skinned off, roots and all, with a bulldozer or root rake.

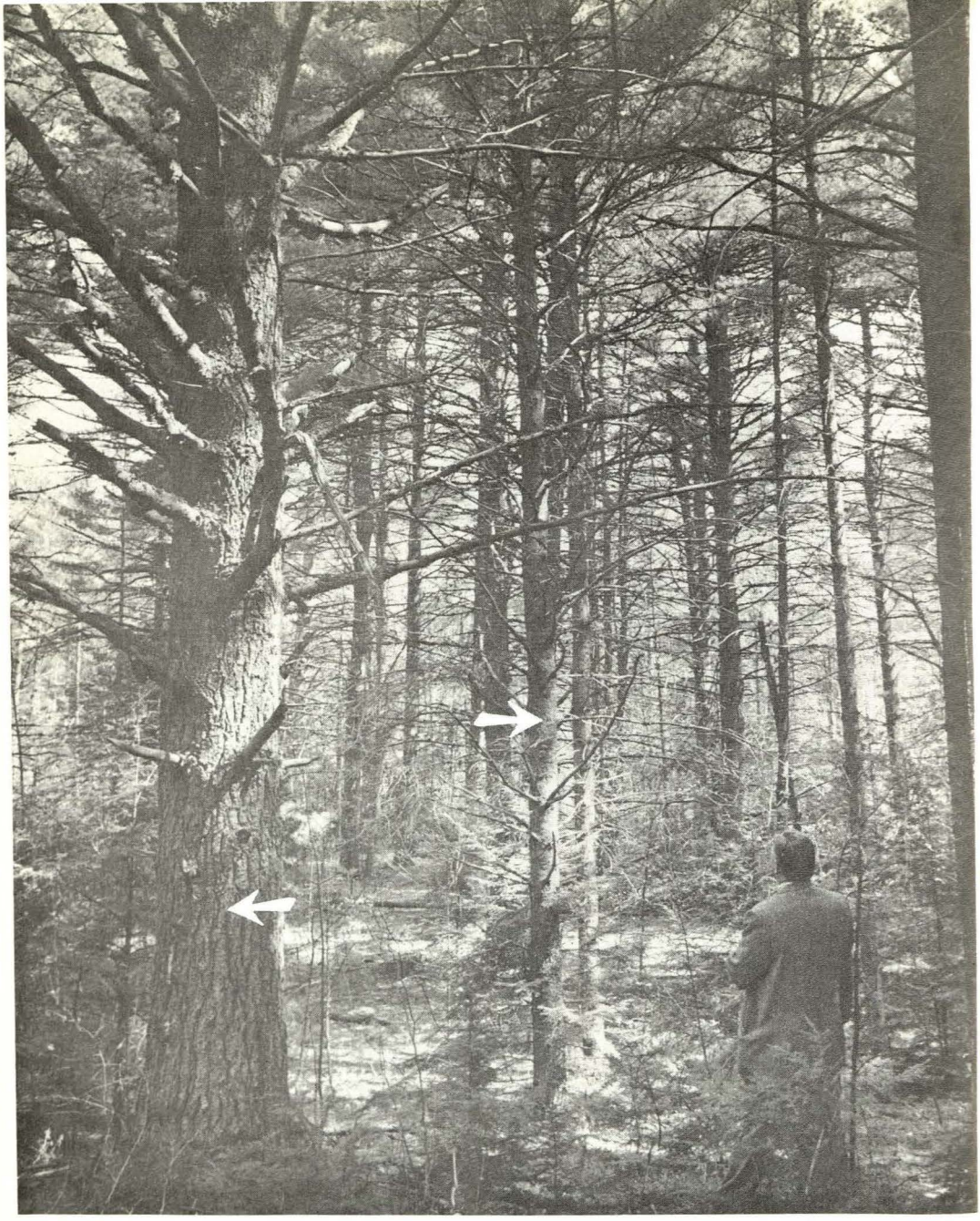
A major disadvantage with all power equipment is that its use may be restricted by stony soils and rough terrain. Disks are poorly suited for use on stony soils. Bulldozers and root rakes can cope with a considerable degree of stoniness, but where stones are so dense that the machine tends to skid over rather than bite into the ground, site preparation by any kind of earth-moving equipment becomes impracticable.

In tests of various kinds of equipment in stony soils of the scrub oak type in Pennsylvania, a root rake on a crawler tractor of the D-6 or D-7 class has worked best. This machine has done an adequate job except where stones formed practically a continuous layer on or in the surface soil. The brushy vegetation was removed in discontinuous strips amounting to about one-third of the total area. Costs



One of the major quality degraders: a large, black, encased knot. A few of these will degrade a board to No. 4 Common.

Slight bumps and distortions in the bark pattern indicate hidden lumber degraders in the otherwise clear white pine butts. Traces of the nodes can still be seen on the tree at the left.



The tree at left is beyond help; no forest-management treatment could improve its quality. Its wood contains many large, black knots.

The smaller tree in the center offers an opportunity for quality improvement through pruning--provided its crown is large enough so it could grow rapidly after release.

Size of crown in relation to stem indicates that the tree at left is growing twice as fast in diameter (2 inches in 10 years) as the tree at right. Because of its small crown, the tree at right is unlikely to increase growth very much as a result of release.

Evidence of damage many years ago by white-pine weevil.

Upper photo: the stub pointed to is the remains of an old weeviled leader.

Lower photo: the swollen node and distorted branches show that here the leader was weevil-killed and the lateral branches competed to form a new leader.

A successful shelterwood cutting with reproduction,
on the Pack Demonstration Forest, Warrensburg, N.Y.

White pine for the future? A group-selection system of silviculture brought about this stand. Notice the different age classes, small seedlings in foreground.

for this treatment at 1958 prices were in the range of $15 to $20 per acre.

The idea of a rugged, 2-way pusher plow on a heavy crawler tractor has occasionally been proposed for planting-site preparation in stony brushlands, but in the past no such equipment has been available. Recently, advertisements of a plow of this type have appeared (Anon. 1958), with the description of its performance oriented to stone-free soils in the South. Although we have no information on how well this plow would work in stony soils, it would seem worth investigating.

Chemical Methods

Chemical methods of site preparation are based mostly upon use of 2,4,5-T. If there are scattered cull trees, other chemicals such as ammate or sodium arsenite may be used on them; ammate also is a possible, but little used, alternative to 2,4,5-T for treating growth of a brushy character.

2,4,5-T may be sprayed on brush with hand equipment, power ground equipment, or by aircraft. With ground equipment, it may be applied as a foliage treatment or as a basal stem spray. We have considerable empirical information on methods for applying 2,4,5-T and the results likely to be obtained. But many of our northeastern hardwoods are fairly resistant to chemical treatment. It is important, therefore, that the practitioner be well informed about silvicides, and that he choose the method best suited to his needs.

Foliage or, more properly, stem-foliage spraying with ground equipment (except mist-blowers) usually is done with low concentrations of the chemical and high volumes of water or oil-water emulsion as the carrier. Four pounds of 2,4,5-T acid equivalent per 100 gallons of carrier is a common concentration. Volumes vary widely with height and density of the brush, from perhaps 100 gallons per acre on low, open cover up to 500 gallons per acre on tall, dense growth. Leaves should be wetted on both sides, together with all twigs and the stems, to ground line. This can be done best with the strong blast of a power sprayer operating at 200 to 300 psi. Such treatment will top-kill most hardwood brush, but considerable resprouting by the more resistant species, such as the maples, can be expected.

Basal-stem sprays are done with 2,4,5-T in oil solutions (diesel oil, fuel oil, or kerosene). Concentrations of 8 to 16 pounds acid equivalent per 100 gallons are used. Hand sprayers of the back-pack type serve very well, as only low pressures are required. With thorough application, wetting every stem base to the point of copious run-down, a high percent of root-kill can be accomplished by this method. However, it is slow and comparatively expensive in both

labor and materials; and if not done properly, results are no better than with foliage treatment. Its most practicable use in forestry probably is in weeding operations where only selected stems or clumps need be treated.

Aerial sprays are low-volume, high concentration applications, with either oil or oil-water carriers. One to two pounds of 2,4,5-T acid equivalent in $2\frac{1}{2}$ to 5 gallons of solution or emulsion per acre are used. Similar applications can be made with a mist-blower. Small rigs that can be mounted on a tractor are best for forestry work. Backpack mist-blowers also are useful for controlling understory hardwoods in pine stands where it would not be practicable to bring in heavier equipment.

For jobs of more than an acre or two, chemical treatment by hand or simple power equipment becomes a formidable job. Moreover, use of power ground equipment may be limited by rough terrain. Consequently, aerial application is especially attractive for the larger jobs, both because it is not limited by terrain, and because of its comparatively low cost. It may be done at costs well under $10 an acre when an operator can do at least 150 acres in one locality (McConkey 1959).

There are very few precedents in the Northeast for use of aerial spraying as pre-planting site preparation. The jobs that have been done are too recent to permit a final judgment of results. Consequently, what is said here is more or less speculative. We do know that aerial spraying will not usually give a high percentage of root kill in mixed northeastern hardwood brush. It will give good top kill, plus some root kill of the more sensitive species. If there is not a turf-like ground cover of low blueberry, bracken, or other stoloniferous species, we believe pines could be successfully planted after the spray treatment. If a turf-like ground cover were present and survived the spray treatment, planting would not generally be advisable because of the intense root competition. In all probability, pines planted following an aerial spray in hardwood brushland will require one or more repeat sprays at intervals of 2 or 3 years to release them from resurging sprouts. On good white pine sites, a total of two, or even three, aerial sprays might be economically feasible.

All chemical methods leave much to be desired as a site-preparation measure. They do not improve the seedbed for seed regeneration, and they leave standing dead brush, which greatly impedes hand planting. To accomplish the desired degree of root kill of many species requires intensive treatment by men on the ground; getting the necessary equipment to and over the planting sites often is difficult. The chemicals that will kill grass leave toxic residues for a year or more.

The upshot of the silvicide situation as it stands now is that aerial sprays with 2,4,5-T often do not do as good a job as we would like; for all practical purposes, some sites are inaccessible for ground treatments; and on accessible sites really effective ground treatments often will cost more than we can afford. Silvicides are without doubt a useful tool, but their limitations and disadvantages must be recognized; they do not ipso facto solve the problem of controlling hardwoods and regenerating pine. There still is room for much research, both basic and applied, in this field.

REGENERATION METHODS

Three general methods for establishing white pine (or any other species) on open land can be considered: (1) natural seeding, (2) direct artificial seeding, and (3) planting nursery-grown or wildling seedlings. Although planting nursery-grown stock is the method most commonly used, the others may serve well, and sometimes cost less, in situations to which they are suited.

Natural Seeding

In the past, natural seeding was the means by which practically all old-field white pine in the Northeast became established. This means can still serve us well in the occasional instances where sparsely vegetated land (such as recently abandoned crop land) lies adjacent to a good white pine seed source. However, the range of seed dispersal is limited; good stocking becomes increasingly uncertain at distances greater than 200 or 300 feet.

Natural seeding of white pine is somewhat unreliable because of the uncertainty of seed crops. Between the ravages of cone insects and seed failures caused by climatic or physiological factors, periods of 10 years or more may pass without substantial seed production. A site that initially was receptive may go into heavy sod or dense brush before a seed crop materializes.

Where a densely vegetated site lies close to a promising seed source, natural regeneration might be greatly increased by site preparation timed to coincide with a maturing seed crop. But regardless of site condition, if no seed crop is in sight and regeneration is desired without delay, the landowner had better turn to artificial methods.

Direct Artificial Seeding

Direct seeding of white pine has been done only experimentally, and mostly with negative results. However, southern pines and western conifers are being successfully

seeded. There is no obvious reason why reasonably dependable methods for white pine could not be developed; but there is one obvious difficulty as compared to those other species and regions--the relative scarcity of white pine seed.

The most important recent advance in direct-seeding methodology has been the development by the Fish and Wildlife Service of an effective means for protecting seed against birds and rodents. This technical break-through underlies the successful use of direct seeding in the South and West. The basic ingredients for seed treatment are Arasan to repel birds and Endrin to poison or repel rodents.

The Station is now conducting studies on direct seeding white pine on the Massabesic Experimental Forest. These involve both empirical tests of repellent-treated seed, and more basic studies of the effects of shade, ground-cover competition, and animal depredation.

Direct seeding is done in one of two general ways: (1) controlled placement of seeds in spots or drilled in furrows; and (2) broadcast seeding. The former involves hand labor, and may cost almost as much as planting. It has little appeal except possibly on small tracts where use of heavy equipment might not be feasible.

Broadcast seeding lends itself to mechanization, either on the ground or by aircraft. If it is successful, substantial savings are possible. It simulates nature, but since we cannot afford to spread seed as lavishly as nature does, seed protection and site preparation are especially important. All past experience warns against gambling on broadcast seeding without preparing the site. More than 20 years ago Shirley (1937) wrote: "There seems to be no more certain way of wasting a large amount of seed, and accomplishing nothing, than to broadcast it on unprepared soil".

Site preparation for seeding should provide: (1) a mineral soil seedbed; (2) a roughened surface to facilitate seed coverage; and (3) a light plant cover sufficient to cast dappled or patchy shade, but so reduced as not to be highly competitive. With these conditions, normal weather, and treated seed, there seems a good chance that broadcast seeding would succeed. However, since local precedents are lacking, any such seeding at this time should be done only on an experimental basis.

Planting

The planting of nursery-grown seedlings is a proved and reliable method for establishing white pine on open land. There are no particular problems in the nursery or in the planting operation. For hand planting, any of the standard hole or slit procedures may be used. Most nurseries distribute 2-0 or 3-0 seedlings. Few transplants are produced.

Although wildling stock plays an insignificant role in the overall regeneration picture, it merits mention as a supplemental source of supply. Wildlings ordinarily would be used only by a farmer or private landowner wishing to plant a few hundred trees. If he had easily lifted wildlings available, it would be entirely feasible to make use of them in a small one-man or family planting job. If labor had to be hired, wildlings might cost as much or more than nursery stock, and their use would offer no advantages.

With uniform nursery-grown stock, planting machines work well on reasonably open, smooth land; they will plant up to 10,000 trees per day under favorable conditions. On most sites, however, accomplishments are considerably below that figure because of impediments of one sort or another--rough terrain, stones, stumps, slash, or standing brush. On the Massabesic Experimental Forest, machine planting by a 2-man crew on areas within the 1947 burn has ranged from 1,500 to 4,500 trees per day; the average rate for 186 acres was about 3,400 trees per day. For the moderately rough conditions encountered on this job, a custom-built V-blade was mounted on the front of the tractor to clear loose slash from the line of travel, and special reinforcing was added to the planter.

The Lowther Company makes a "rough-land-planter" based on the same principle as the Massabesic outfit; that is, a trash-clearing blade in front, followed by a ruggedly constructed planter. The Lowther equipment, however, is somewhat more elaborately designed, and more costly. The blade in both outfits is simply skidded along the ground surface, pushing loose debris aside; it is not very effective among solid stumps or partially buried stones.

In Rhode Island a private inventor for several years has been working on a rough-land planter designed for control by the man on the planter, rather than the man on the tractor. Among stones, stumps, and the like, the operator can raise and lower the planting shoe as necessary to clear obstacles; he can stop and start the tractor at will and plant the trees in selected spots along the line of travel. The Rhode Island Department of Agriculture and Conservation, Division of Forestry, has recently acquired a custom-built model of this machine for use on rough burned-over forest land. Anyone with a rough-land planting job will be well advised to investigate what this machine will do.

Even with rough-land planters, there are many sites capable of growing trees that are too stony, too steep, or cluttered with too much down timber or heavy slash for mechanized planting. On these areas one must still rely on hand methods.

One of the debatable questions in planting white pine is the spacing. The traditional 6 by 6 feet still is widely

practiced. Spacing at 5 by 5 has been advocated by some as an aid in overcoming weevil damage--the crooks resulting from killed leaders are less pronounced when the trees are crowded. The trend now, however, is to space wider and spray against the weevil.

Spacing at 8 by 8 feet or wider reduces planting costs and gets away from non-commercial thinnings, but requires properly timed pruning as well as weevil control if tree quality is not to suffer. Actually, on the rougher lands that make up most present-day planting sites, spacing becomes a somewhat academic question. Of necessity, the spacing will be irregular. Generally it will average wider than 6 by 6. The practical objective is to get a reasonably adequate stand; adherence to a regular spacing pattern would be an unjustifiable refinement. In any event, there will have to be weevil control, pruning, and probably some thinning to produce quality pine.

SUMMARY

Site preparation is required for establishing white pine on most open land in the Northeast because of the usual presence of hardwood brush. Mechanical preparation with plows, bulldozers, or root rakes is effective where soil and terrain permit use of such equipment. Silvicides offer an alternative method, by which competing brush can be set back; but for natural regeneration the seedbed is not improved. Aerial spraying has considerable appeal because of its relatively low cost and its independence of ground conditions. However, in many brush types, spraying may have to be repeated one or more times to bring young pines through.

Planting is the usual method for establishing pine on open land. Direct seeding has been done only experimentally, without marked success, and natural seeding is limited to zones within 200 to 300 feet from a seed source. Rough-land planting machines have been developed that work satisfactorily under moderately rough, stony, or trashy conditions; but there are many situations where hand planting is the only way.

Spacing at the traditional 6 x 6 feet is not practicable in most rough land planting; irregular spacings averaging around 8 x 8 or wider are acceptable practice.

Managing Young Stands for Quality Production

by Richard D. Lane

PRODUCTION of high-quality white pine must begin in young stands. The immediate objective of management in young stands is to develop a growing-stock "base" on which quality growth can be accumulated rapidly during the latter part of the rotation. The best way to reach this objective depends upon a number of factors, of which stand conditions and the amount of management effort available for the job are the most important.

In any case, the application of several management practices is required to bring white pine reproduction through to a satisfactory stand of large poles and small sawtimber. The four most important practices in young-stand management are: (1) protection; (2) weeding and releasing; (3) thinning and stand-density control; and (4) pruning.

PROTECTION

Since protection is a prime requisite to any management program, it may be redundant to even mention it here. Fire protection certainly is a "must", especially in young stands.

Grazing and Browsing

The pros and cons of cattle grazing in seedling and sapling stands of white pine have been argued at length in the literature. A special committee of the New England Section, Society of American Foresters (1929), has given a well-rounded report on the use of grazing as a cultural tool in white pine management. The Committee reported that any forest grazing causes some damage, chiefly through trampling, scarring, and breaking young pines. Where grazing is uncontrolled, the damage can prevent the development of a white pine stand. But by carefully controlling the time and intensity of grazing, the amount of damage can be reduced to the point where it is more than offset by the value of release from competition afforded the pine stand. The Committee concluded that grazing, as a cultural tool, is not widely useful but that some woodland owners may be able to employ it advantageously.

Except in local spots or under starvation conditions, deer browsing of white pine usually is not severe in the

Northeast. The best control measure for browsing is, of course, to manage the deer herd to keep it in balance with available food supplies. The Fish and Wildlife Service and the Forest Service are cooperating in screening potential chemical repellents for deer and rabbits. As yet no completely effective chemical has been discovered. McQuilkin and Little (1952) tried one of the more promising repellents and reported that it offered no protection to white pine in Pennsylvania.

Snow and Wind

Snow and wind damage are the most serious types of weather injury to young white pine. Of the two, snow is the lesser enemy. Curtis (1936) states that white pine is occasionally subject to snow breakage if the trees are closely spaced and have one-sided crowns. The Lake States Forest Experiment Station (1939) has reported that the species was damaged only slightly by a heavy wet snowfall in late October. Such damage as did occur was to trees 4 to 9 inches in diameter--larger trees were not damaged at all.

Damage done to central New England stands by the 1938 hurricane indicates that: (1) up to about age 25, white pine is more resistant than either Scotch or Norway pines; (2) trees with long, open, or small crowns and thin, flexible trunks are the most wind-resistant; (3) the greatest damage is likely to occur on exposed slopes, especially on south-facing ones; and (4) the older, denser, even-aged stands are the most susceptible to wind damage (Curtis 1943). Curtis suggests early thinning in young stands to develop firmly rooted dominant trees with crown ratios (ratio of crown length to total height) of 40 percent or more. He also suggests leaving a dense belt of trees in stand perimeters and making light but uniform thinnings in older stands to avoid open holes and dense clumps.

Disease and Insects

The more serious pests of white pine are discussed in other papers of this series. However, it may not be overworking the subject to mention here the two silvicultural methods that are at least partially effective in controlling white-pine weevil damage. They are: (1) bringing young pine up through an overstory of hardwoods (Peirson 1922, Young & Eyre 1937); and (2) developing and maintaining dense, pure, even-aged stands (Hawley & Clapp 1942, Lutz & Cline 1947, Tarbox & Reed 1924). Thus, some silvicultural control of weeviling appears possible, but only at the expense of tree growth.

WEEDING AND RELEASING

Of all white pine management practices, weeding and release treatments in seedling-and-sapling stands are probably the most difficult to apply effectively. From the mass of scattered information on the competition among species, on the structure and composition of preferred stands, and on the tools and techniques of treatment, two facts seem quite clear:

- Some weeding would be beneficial in nearly every seedling-and-sapling white pine stand. In many such stands it is vital to the production of a pine crop.
- Weeding is a relatively costly cultural practice--even with silvicides.

With these facts in mind, a few guidelines to weeding practice can be discussed briefly.

An ideal weeding chance is a stand well stocked with white pine seedlings about 4 years old and overtopped by hardwood seedlings and sprouts. Here there may be several treatment options: (1) begin the weeding at once to produce a dense, pure pine stand; (2) delay weeding until competition has reduced the pine stocking, then weed to produce a moderately stocked, pure stand; (3) on the better sites delay weeding until competition has reduced the pine stocking and the better hardwoods have become a dominant component, then weed to produce a mixed stand of pine and desirable hardwoods.

To obtain a dense, pure stand, weeding must be applied early before the pine stocking is seriously reduced by competition. All the hardwoods must be removed. If the weeding is done with cutting tools, treatment may have to be repeated as many as four times. This method is expensive but it is sometimes the only one practical when the area to be treated is small. Aerial spraying of silvicides for a weeding treatment can be done economically on areas as small as 15 acres, provided that the acreage of such small jobs adds up to at least 150 acres (McConkey 1958, 1959). On smaller jobs the spray may be applied with simple hand or power sprayers or with one of the newer mist-blowers.

Delay of the weeding will reduce the pine stocking and may also reduce the costs. We cannot predict how long the treatment may be delayed but we do know:

- Intensity of competition varies with competing species and site quality. Gray birch is not a strong competitor (Toumey 1919) and pine will frequently come through both gray and paper birch unaided and in substantial numbers. On the other hand, the maples--particularly red maple--always

offer strong competition to white pine. Aspen and the oaks are intermediate in the competition they offer (Lutz & Cline 1947, Cline 1929, Spaeth 1922, Young & Eyre 1937). The intensity of competition offered by any species is greater on good sites than on poor sites.

- "...there is a practical height for the white pine at which, if the hardwoods are removed, the released pine will not need further attention." (Minuse as quoted by Spaeth, 1922). On medium-quality sites in the Harvard Forest this height is 15 feet if the competition is aspen, and 12 feet if it is red maple. In the Lake States (on what may have been poorer sites) the equivalent heights are about 8 feet if the competitors are aspen and about 6 feet if they are red and white oak (Engle 1951). The stands will be about 20 years old when this height is reached.

Aerial application of foliage spray is a good delayed-weeding treatment when relatively large areas are involved. Where ground methods must be used, small competitors should be cut with hand tools or killed by basal spray of silvicide. However, stems over about 4 inches in diameter are most economically killed with silvicide-dosed single-hack girdles, frills, or spaced ax cuts (McQuilkin 1957, Little & Mohr 1956, Curtis 1956, Rushmore 1958). The treatment should be selective. No more work should be done than is necessary to fully release, say, 300 well-spaced pine to the acre and, on the better sites, to moderately release an occasional good hardwood where the pine is lacking.

On good sites, and where there is a substantial number of good hardwood stems, it may be better to work for a mixed rather than a pure stand (Cline & Lockard 1925). We don't know yet how to determine the breaking point, but we do know that the mixed stand is cheaper to develop on small areas, has less weevil damage and better knot characteristics, and may contribute to improved growth and vigor of all trees in the stand (Lutz & Cline 1947). To favor mixed stands, the groupwise arrangement of the hardwood and pine components that frequently develops naturally should be encouraged. In the pine groups, full release should be given the whole group. In the hardwood groups, release should be selective and moderate to favor the best hardwood stems without permitting room for excessive crown expansion, epicormic branching, and the like. Of course aerial foliage sprays cannot be used in developing pine-hardwood stands. With these exceptions, weeding practice in mixed stands is the same as pure stands.

This covers the important weeding alternatives. Treatment of the older seedling-and-sapling stands that already exist will parallel that discussed above as delayed treatment. Weeding in stands that are not adequately stocked with pine or good hardwoods is an uncertain investment. Re-

lease of available growing stock may keep the area at least partially productive and ultimately provide a seed source for the next stand. If the stand is young, it may be worthwhile to seed for additional stocking by methods described earlier by McQuilkin. Or, it may be better simply to forget the stand and make the investment where the opportunity is greater. The decision here is beyond the scope of a weeding discussion.

THINNING

Like weeding, thinning for production of quality sawtimber can be done in several ways: low thinning, crown thinning, selection thinning, and mechanical thinning--each at several intensities (Hawley & Smith 1954). The choice of method depends largely on stand conditions and on the overall intensity of the management program.

Low Thinning

Low thinning has been by far the most widely practiced method in white pine stands. Originally designed primarily to salvage trees of the lowest crown classes that otherwise would have died, the method found particular favor in white pine because it also holds down average branch size, permits a relatively high rate of natural pruning, and reduces stem deformation from white-pine-weevil injuries. Cultural costs are thereby held down while maintaining good prospects for a high-quality final yield. Finally, relatively little skill is needed to select the trees to be cut.

On the other hand, even when thinning is moderately heavy, little additional growing space is provided for the residual trees of the upper crown classes, so the growth of these trees is not greatly accelerated by the thinning. Consequently, the sawlog rotation is relatively long. Intermediate yields are generally of low value because they are the product of small trees of the lower crown classes. The high stand density upon which the method is based is often hard to maintain and causes the stand to be more susceptible to wind and disease damage.

Low thinning has its chief value in dense stands and in stands on the better sites, and in situations where reduction of cash outlays for cultural work is more desirable than reduction of the number of years needed to grow the crop.

There are several notable examples of the low-thinning method applied consistently on small plots over periods of 30 years. In the Saginaw Forest in southeastern Michigan (Spurr et al. 1957), the Biltmore Estate in western North Carolina (Wahlenberg 1955) and the Yale Forest in south-

western New Hampshire (Hawley 1936), light to moderately heavy low thinnings at 5- to 7-year intervals each removed about 10 to 20 percent of the stocking. In none of these examples was an increase shown in gross yield--the total growth of wood whether or not it was usable.

However, net yields--the amount of wood that could be used--was 12 to 35 percent higher where thinning had been done. In the Biltmore example, the thinning advantage was greater in terms of total board-feet (52 percent) than in terms of total cubic feet (35 percent). This reflects the faster increase of average stand diameter in the thinned stands. In both the Biltmore and the Saginaw low thinnings the actual average diameter growth rate was only slightly better in the thinned than in the unthinned stand, however. The increase in average stand diameter resulted almost wholly from cutting more small trees than would have died had the thinnings not been made.

Wahlenberg found an average live crown ratio of 42 percent after the first thinning in the 20-year-old Biltmore plantation, compared to a 34 percent ratio in the unthinned plot. At the age of 56 years, after a series of seven thinnings, the thinned plot had a live-crown ratio of 37 percent and the unthinned plot a ratio of 29 percent. Wahlenberg states that a crown ratio less than 35 percent (for which diameter growth is about 1 inch in 10 years) is unsatisfactory. Evidently these low-thinning regimes were barely sufficient to keep the average crown ratio above the minimum level. Spurr and his associates concluded that heavier thinnings are necessary to keep the trees retained growing vigorously to the end of the rotation. Although the data from these examples are certainly not conclusive, they suggest that this kind of thinning is preferable on the better sites.

Crown Thinning

Largely as a result of experience with low thinning, more recent recommendations prescribe crown thinning. Here most of the trees cut are in the codominant crown class but some trees in the dominant class and some in the lower crown classes also are cut, depending upon spacing requirements and the value and quality of the trees. The principal advantages over low thinning are: (1) The intermediate yields are generally of higher value because they come from larger trees, (2) The crown space available to residual trees is increased, thus permitting more rapid diameter growth and a reduction in the time needed to produce sawlogs of a given size. Total net cubic-foot yields may be less than in low thinning but total net board-foot yield may be greater. If crown thinnings are started early enough, the stand should have greater resistance to wind and disease damage.

Successful application of crown thinnings requires

greater silvicultural skill than does the practice of low thinning. And the tendency for more open-grown trees to be of poorer quality must be overcome by more intensive application of other cultural practices such as pruning and weevil control. Therefore, cultural costs are generally higher for crown thinning. As trees grow older their rate of crown expansion becomes less. It seems almost inevitable that some growing space will be wasted by crown thinning in the later stages of the rotation.

Nevertheless, crown thinning offers a better opportunity than low thinning for rapid production of quality sawtimber. It is the preferable thinning method for those who are willing to make some investment in cultural practices in order to shorten the rotation. It is particularly applicable in stands on poor sites and in stands where severe competition has not yet started.

Selection Thinning

Selection thinning has found favor among foresters dealing with young or previously unmanaged white pine stands because it offers opportunities to thin early and to concentrate the cut on the large, coarse, and crooked or multiple-stemmed dominant trees that are often found in such stands. Selection thinning is the opposite of low thinning. The cut progresses downward from the dominant crown class as the thinning intensity becomes progressively heavier. Trees presently in the lower crown classes are depended upon to produce future yields.

If the stand is in such poor condition that the trees cut in thinning are almost all of clearly undesirable quality, then the selection thinning is no different than crown thinning in practice. Such thinning seems to have ample justification. However, when selection thinning requires the cutting of a substantial proportion of the good quality dominant and codominant trees, use of the method should be carefully scrutinized.

The main justification for true selection thinning in white pine is that stands commonly need thinning before a "commercial" low thinning or crown thinning can be made. This point is reached when mortality is accelerated by rapidly increasing competition within the stand. (Smithers 1954, Tarbox & Reed 1924). It often occurs when the stand is about 30 years old, although the exact age is a function of site quality and stand density. Increased mortality is signaled by a sharp reduction in diameter growth. For example, in the Harvard Forest this has occurred in stands 30 years old and 40 feet tall (Tarbox & Reed 1924). When average stand diameter is about 4 to 6 inches at this time, the only trees from which products can be obtained are the larger dominants and codominants.

Thus, selection thinning, while reducing cultural costs, lengthens the rotation. If carried out close to the time when thinning is first needed, selection thinning can improve quality production. If it is delayed until the crown size of the trees in subordinate crown classes is very much reduced, it can be disastrous. Repeated selection thinning can produce small products such as pulpwood but is incompatible with the rapid production of high-quality sawtimber (Hawley & Smith 1954).

Mechanical Thinning

Mechanical thinning includes all those methods based on a regular spacing or pattern of tree removal rather than the crown class and quality of the individual trees. Row thinning in plantations is a prime example of mechanical thinning. In general, mechanical thinnings are applicable to the same situations as selection thinning and are subject to the same restrictions. They are particularly useful for early thinning in plantations where tree development is relatively uniform. As a rule mechanical thinnings are less detrimental to sawtimber production than selection thinning because a smaller proportion of the good-quality dominant trees is cut. However, they produce less immediate timber value because some of the trees cut will be marginal or submarginal in value.

In contrast to selection thinning, mechanical thinnings can often be repeated several times in the production of sawtimber, but such thinnings should be supplanted by crown thinnings as soon as possible.

Conclusion

Although the four thinning methods have been discussed as exclusive choices, the distinctive features of a method are often hard to identify in practice. The appearance of a stand thinned by a given method will naturally vary as the original condition of the stand varies. And, there is no rule requiring that any of the methods be used in their purest form. Indeed, it is often preferable to employ some compromise between two methods, and the product objective may best be reached by changing from one method to another during the life of the stand.

Stand conditions dictate the choice. Thus, early selection thinning may be replaced by crown thinning until the stand is of sawtimber size, to be followed by low thinning during the rest of the rotation (Hawley & Smith 1954). This pattern appears to have considerable merit for sawlog production in many white pine stands because it makes the best use of the stand and the site on which it grows at every stage of development.

This discussion has centered on particular, idealized situations. But, more often than not, the forester will deal with atypical situations. He must devise thinning regimes to fit them. In doing so, the principles evolved from past thinning studies must be considered in terms of the management intensity that can be practiced and the appropriate product objective. For rapid production of quality sawtimber, thinnings in young white pine stands ought to follow these guidelines:

- Crown thinning, repeated often, to give crop trees room to expand.
- Selection of at least enough well-distributed crop trees to compose a final stand with the desired average diameter and stand density.
- Maintenance of a below-normal or understocked condition, so as to retain at least a 35-percent live-crown ratio on the crop trees.

STAND-DENSITY CONTROL

"Basal area per acre is possibly one of the most important criteria on which thinning practice should be based", according to Smithers (1954) in his illuminating report on a number of thinning experiments in red and white pine stands in the Ottawa Valley. He uses basal-area development to propose crown-thinning regimes for these stands, by site classes.

The first thinning is made at about age 30 when natural mortality begins to accelerate, if stocking is normal. On one of the better sites (site index 55) thinnings that remove about 15 percent of the basal area are made at 5-year intervals until age 50. Thereafter, thinnings are made at 10-year intervals; and about 10 percent of the basal area is removed each time. Under this practice the stocking level is gradually reduced from normal at age 30 to 70 percent of normal at about age 55 and then is allowed to build back to normal at rotation age of 100 years. Mean stocking during the thinning period increases at a nearly linear rate of about 1.7 square feet annually. The final normal yield is 7,500 cubic feet contained in 160 trees with a mean diameter of 16 inches. The thinnings yield an additional 3,200 cubic feet.

Smithers imposes two important qualifications on the use of the thinning regimes: (1) Crown thinning must be used to favor carefully selected, well-distributed crop trees. (2) The thinnings themselves must be well distributed over the area. By these means the full benefits of thinning can be realized.

Heiberg (no date) has developed a thinning regime for white pine plantations on good sites in the Adirondacks that is somewhat different. The first thinning is made at about 24 years. It is repeated at roughly 5-year intervals to rotation age, removing about 25 square feet of basal area in each thinning. Under this program the mean stocking increases slowly. It builds up at a regular annual rate of $\frac{1}{2}$ square foot from about 130 square feet at the first thinning to about 155 square feet at the last--84 years. This appears to cause a gradual reduction of stocking level from near normal at the first thinning to about 60 percent of normal at rotation age. The yield at 84 years is 6,200 cubic feet contained in 85 trees averaging 19.0 inches in diameter. Intermediate yields add 7,700 cubic feet to the gross. Heiberg, too, stresses the need for well-distributed crown thinnings to continually increase the growing space available to crop trees.

PRUNING

One of the least desirable features of white pine is the number and persistence of branches. Thus artificial pruning at an early age is the surest way to control knot characteristics and to obtain clear lumber. It is the only practical way in stands that are well thinned.

Considerable research has been done in pruning white pine. This work has provided the following important guides:

- Pruning may be done in one or in several steps. For purposes of quality growth alone, frequent light prunings are preferred over a single heavy pruning (Smithers 1954). This practice will help hold the crown ratio at a desirable level, will yield a small knotty core of uniform diameter, and green pruning may reduce the incidence of "black" knots.

- Between one-third and one-half of the live crown can be removed in pruning without serious loss of growth (Barrett & Downs 1943, Smithers 1954). Bud pruning has been tried on white pine (Fox 1957, Doolittle 1954), but trees pruned this way seem to "attract" more than the usual number of white-pine weevils. Therefore, it is not recommended.

- The amount of crown that can safely be removed is also subject to the restriction that at least one-third and preferably one-half or more of the total stem length be in live crown for the best growth (Wahlenberg 1955, Smithers 1954).

- Pruning should be done in the dormant season for best healing (Adams & Schneller 1939).

- Live branches over 2 inches in diameter should not be pruned because of the high cost, slow healing rate, and

danger of decay (Hawley & Clapp 1942). Campbell (1956) states that healing time ranges from 1 to 5 years for knots from ¼ to 1 inch in diameter. And a study made in Maine by Davis (1958) indicates that about 1.3 inches of growth is necessary to completely heal the largest knots pruned on white pine averaging 7.7 inches d.b.h. at time of pruning.

- The number of trees to be pruned should at least equal the number expected to make up the stand at the end of the rotation. How many more might profitably be pruned is problematical, but certainly more--perhaps 30 percent more--than the minimum should be pruned if pruning is started early. This will compensate for mistakes in tree selection and accidental loss of pruned trees, and will produce some clear lumber from later thinnings.

SUMMARY

In managing young white pine stands for quality production, these practices are known to be important: (1) protection is a prime requisite; (2) weeding and releasing will be required in most seedling and sapling stands; (3) thinning is needed for the rapid production of high-quality poles and small sawtimber; and (4) pruning is the surest way to grow high-quality and sound-knotted white pine lumber. Although additional knowledge is needed, application of that now available will increase substantially the production of high-quality white pine in the Northeast.

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Managing Merchantable Stands for Quality Production

by Charles R. Lockard & William E. McQuilkin

IN general terms, merchantable stands are those that contain a sufficient number of trees large enough to yield products that can meet minimum use requirements, and that can be harvested at a profit.

HOW TO HARVEST

Under modern management concepts, the harvest cuts should: (1) remove products as efficiently as possible, and (2) result in a new stand of the desired species--white pine, wholly or in part, in this case. It is usually necessary to effect some compromises in the method of operation to accomodate these two objectives.

Only one point need be made about the mechanics of the harvesting operation itself; namely, that the operation be directed toward capturing the maximum of the potential tree values. To do this, it is necessary to understand the factors that affect values adversely. This implies a more scientific approach to log-making than is generally taken. For instance, inability to recognize weevil incidence may result in failure to make bucking cuts at a point in the bole that will minimize damage and avoid significant loss of potential value. Similarly, lack of knowledge of the effect of knot character, as seen in the log, on lumber grade pattern, and the consequent failure to alter log length in accordance with knot characteristics, also will adversely affect yields of the higher lumber grades.

As to reproduction of the stand: Several choices of cutting methods are available, the choice depending upon the condition of the stand and the environmental modifications necessary to obtain reproduction on the particular site. These cutting methods are: (1) clear-cutting; (2) shelterwood cutting; (3) shelterwood-with-standards cutting, leading to two-storied forest; and (4) clear-cutting by small areas--group, patch, or strip cuttings. Clear-cutting in large blocks commonly leads to regeneration problems, and is seldom advisable unless the owner is prepared to replant. Both practical experience and studies of silvical requirements indicate that the shelterwood system of cutting white pine stands offers the greatest assurance of reproducing the species by natural seeding.

The shelterwood system is defined as "the removal of the mature timber in a series of cuttings, which extend over a period of years equal usually to not more than one-quarter and often not more than one-tenth of the time required to grow the crop, by means of which the establishment of natural reproduction under the partial shelter of seed trees is encouraged" (Meyer & Eyre 1958). A shelterwood-with-standards means that, at the time of the final cut, a limited number of high-quality trees are reserved for continued growth through part or all of the next rotation.

The purpose of standards, as will be discussed later, is to permit trees with high-quality potential to produce large quantities of wood of superior quality by utilizing the ability of white pine trees to grow well for long periods as isolated individuals. From the standpoint of getting reproduction, it matters little whether or not standards are carried over. Standards would provide a reserve seed source, however, in case the previously established reproduction were wiped out by fire or other catastrophies.

The advantages of the shelterwood method for establishing reproduction are:

- The opening of the stand by thinnings and partial cuttings promotes breakdown of the litter and improves seedbed conditions.
- The shelterwood canopy retained after the reproduction cut provides the diffused light from high shade that favors seedling establishment. Seedlings must have at least 20 percent of full sunlight to start and grow reasonably well during the juvenile period. This requirement and the fact that the seed source and attendant shade can be retained as long as needed gives opportunity for precise control of stand development by use of the shelterwood system.
- The shade of the shelterwood minimizes the importance of having optimum seedbed conditions because seedbed temperatures are ameliorated. With shade, seedlings can germinate and survive under seedbed conditions that would be intolerable under full sun.
- The retention of a canopy until the pine reproduction is established reduces the competitive effect of the usual invading hardwoods.

The first requirement for getting reproduction is, of course, abundant seed. Seed crops of white pine tend to be cyclic; the Seed Manual (U. S. Forest Service 1948) reports good crops at 3- to 5-year intervals. Recently we have become increasingly aware of the damage done by cone beetles, as described earlier by Brown. Because of the cyclic effect and damage by beetles, intervals of 10 years or longer may

elapse without a good seed crop. For best catches of seedlings, reproduction cuts should be timed with good seed years.

A second major requirement for developing a good new stand by natural seed regeneration is that the seedbed be in a favorable condition. Mainly, this means that the ground be fairly free of understory hardwood trees and shrubs. Although under the shelterwood system the maintenance of some shade until pine reproduction is established helps to restrain the hardwoods, shade alone will not give adequate control, especially on sites with heavier soils. Additional control measures usually will be necessary, either at the time of the reproduction cut, or at other times whenever hardwoods seem to be getting out of hand.

An alternative to the orthodox shelterwood method of reproduction is to clear-cut by small areas--group or patch cutting--or by narrow strips. Here, instead of distributing several periodic partial cuts over an entire stand, each periodic cut is concentrated in selected parts of the stand With these methods, logging and hardwood-control treatments may be accomplished at lowest costs. In highly irregular stands, group or patch cuttings can be distributed so as to harvest clusters of mature trees or clusters of merchantable hardwoods. If the clear-cuts are kept sufficiently small, most of the silvicultural advantages of a true shelterwood can be realized. This means that the width of clear-cut areas should not exceed the height of the bordering trees.

WHEN TO HARVEST

In discussing the "how" before the "when" we have put the cart before the horse. We have done this with intent. "How to harvest" is now a relatively straightforward subject, backed up by a substantial body of literature based on practical experience. In deciding when to cut, particularly in dealing with the rather gloomy prospect of wild stands as they exist today, the forest manager is faced with many additional problems (or opportunities often dimly seen). There are two basically different approaches to the management of merchantable stands.

The first is the stand operation concept. In the past, much consideration has been given to stand management per se. Under this approach, per-acre yields in both volume and value and per-acre growth formed the basis for managerial decisions. Here we average wide variations in growth rate, volume, and value of individual trees. A great deal of literature involving concepts and knowledge on this method of management is available, and most foresters are familiar with it. But not much literature is available on the effect of this type of management on quality of yield. The

wide differences in all respects between trees found in today's stands, and the remarkable ability of white pine trees to thrive as individuals under widely varying stand conditions, make this early approach somewhat anachronistic --certainly it is wasteful of potentials. It appears, then, that a strong and logical approach to management is through individual tree development. Not much research-based information on this method is available, but good examples are common in the forest.

The second is the tree and stand maturity concept. "Maturity" as a basis for cutting or leaving trees is not related to age but rather to potential. A tree is "mature" if its prospective value growth represents inadequate return on the present value of the tree and the space it occupies. Maturity in this sense can be judged from (1) growth rate, (2) extent of weevil damage, (3) coarseness of branch development, and (4) expected improvement or deterioration of the quality factors. Of these, growth rate is partially independent of the others. Actually, a slow-growing tree with the ability to recover and go into a period of accelerated growth can be classified as immature--if it is, or can be expected to become, a "quality" tree. On the other hand, low-quality trees are mature, no matter how fast they are growing--unless there is a prospect for improved quality. This basis for classifying trees (and stands) derives directly from the operation of the lumber-degrading factors. It is a guide to capitalizing on the "upgrading" factors discussed in the section on Markets and Products.

Regardless of age then, in modern forest practice, trees that fall into the "mature" class could be cut at once. The decision to harvest or not to harvest rests on the number of "positive future" trees in the stand. If there are enough of these to form a residual stand of perhaps half normal stocking, then the stand should not be harvested but should be continued under the kind of management described by Lane for "young" stands. The "mature" trees should be cut in thinnings or improvement cuttings.

If the number of "immature" trees is too small to constitute reasonable stocking, or if they are too poorly distributed to make full use of the growing space, the entire stand should be harvested. The method of harvest cutting used can be selected to capitalize on the future of the "immature" trees during the regeneration period. In fact, the shelterwood with standards or "continuous" shelterwood method of cutting advocated by Heiberg and Foster at the Pack Forest is well suited to capitalizing on a few "immature" trees just as long as they remain in that class.

Although data are needed on the rate and degree to which improved quality can be built into a tree, the time required for significant improvement may not be as long as

one thinks. The remarkable ability of a healthy but isolated white pine to continue to grow satisfactorily for long periods of time (perhaps centuries) is well known. This characteristic is the basis for the practice of leaving any "immature" trees--i.e., those capable of good future quality growth--and of carrying these as a stand or as an overstory if necessary. Observations at the Pack Forest at Warrensburg, N. Y., reveal startling value increment on 8- to 11-inch trees of this sort in as little as 20 years. Sorely needed is a comprehensive series of studies to establish not whether it is profitable to manage white pine under this concept, but to establish how profitable it is.

In general, if the potential is to be realized on reserved trees, those trees must be pruned. Except where No. 1 cuts are the principal grade objective, 1 to 3 logs should be pruned. To be most efficient, this operation should be backed by research that establishes the advantages of pruning at various ages, of pruning high or low, and that leads to improved mechanical pruning devices. It should be remembered that the object of pruning is to: (1) produce clears or selects and No. 1 finish by eliminating knots; (2) produce No. 2 finish by working for sound-edge boards; and (3) produce premium by controlling knot character--especially color and tightness. Little effort need be expended on the production of standard or industrial grades; rather, effort should be directed toward not producing them.

It is conceivable that weevil control will have to be carried on throughout most of the life of the tree, for studies have shown that weevils hit high and low.

One final point: The wild stands of the past are not too good an example of the potentiality of the species. In the famous Michigan pineries of the 90's, only 15 percent of output was of the grades we now call "select". Wild trees were always "wild" in quality. In our managed forests, trees should be "engineered". Such trees will have low percentages of the standard, industrial, and dunnage grades, but will run heavy to the profit-bearing high grades.

IV In Conclusion . . .

by Ralph W. Marquis

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THERE are people in the Northeast who are about ready to give up on white pine. Some are skeptical about the mere physical ability of the species to survive, feeling that its natural enemies--fire, windthrow, insects, disease, and hardwood competition--are too powerful to be overcome. Others are inclined to doubt that the ultimate value of a crop will be able to cover the costs of regeneration, management, protection, and waiting. Others fear that present white pine sawtimber supplies will be gone before another crop is ready for harvest and that in the intervening period markets for white pine lumber will be lost forever to other species or substitute materials.

Some might question the propriety of a research organization such as ours--staffed largely by men trained in the biological sciences--peering into the future, weighing imponderables, and deciding the future possibilities of white pine production. But it must be done; otherwise our research program would have no rational direction. We cannot evade the issue and there is no point in being coy about it. The very fact that our research in white pine is being intensified discloses our position, right or wrong.

We are confident that research can point the way to master the natural enemies of white pine and bring it through as a crop. We are so convinced of the superior qualities of white pine in use--if grown, manufactured and merchandised properly--that we believe it can recover any markets it might lose. And our hunch is that growing high-quality pine timber can be an economically sound operation.

All the evidence points to quality as the determining factor. Our confidence in the future of white pine rests entirely on the assumption that sales, manufacture, and timber management will emphasize the quality aspect.

You can't sell quality white pine products unless you manufacture quality products. You can't manufacture quality products unless you grow quality timber. So in the last analysis the future of the white pine economy rests with the forestland owner, and what he does to manage his stands for quality production.

We hope this report may be of some help in pointing the way to this kind of forest-management practice.

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